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Design and Operation of a Device for Evaluating Shaft Seals in Dynamic Applications

INTERIM REPORT
TFLRF No. 371

by

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Clifford A. Moses
U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI)
Southwest Research Institute
San Antonio, TX

for

U.S. Army TARDEC
National Automotive Center (NAC)
Warren, MI

Under Contract to

U.S. Army TARDEC
Petroleum and Water Business Area
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Contract No. DAAE-07-99-C-L053 (WD23)
SwRI Project No. 03.03227.23

December 2003

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13. ABSTRACT (Maximum 200 words)

This document covers the design and operation of a testing device for evaluating elastomeric seals under dynamic conditions at temperatures ranging from 15° to 300°F. Turbojet engine fuel control systems employ sealing surfaces that move or slide over an elastomer sealing material. These seals are generally referred to as dynamic seals, and the ususal configuration is an O-ring. Testing of seals under dynamic conditions is generally required to verify that seal materials are compatible with seals of varying composition. While this device is designed for testing dynamic seals that come in contact with liquid fuels, the device described herein can also be used for testing seals in the presence of other liquids and for applications other than turbojets.

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EXECUTIVE SUMMARY

Turbojet engine fuel control systems employ sealing surfaces that move or slide over an elastomer sealing material. These seals are generally referred to as dynamic seals, and the ususal configuration is an O-ring. Testing of seals under dynamic conditions is generally required to verifiy that seal materials are compatible with seals of varying composition.

A laboratory bench-top test apparatus was designed and built. The apparatus is used for the evaluation of elastomeric O-rings exposed to fuel or other fluids under dynamic conditions and at temperatures ranging from 15° to 300°F.

The test rig can be used to determine the effect of various fluid components and additives on the swell properties of elastomeric materials. While this device is designed for testing dynamic seals that come in contact with liquid fuels, the device described herein can also be used for testing seals in the presence of other liquids and for applications other than turbojets.

FOREWORD/ACKNOWLEDGMENTS

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The authors would like to acknowledge the technical support provided by Elvan Sekula for electrical assistance, Mike Gass for mechanical assistance, and Wendy Mills for administrative and report-processing support.

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1.0 INTRODUCTION

Turbojet engine control systems are composed of a large number of fuel-wetted components that supply the proper amount of fuel to the engine burner and these systems may employ fuel-wetted actuators for the inlet guide vanes, nozzle exit area, and nozzle vectoring. Within these systems are a number of sealing surfaces that move or slide over an elastomer sealing material. These seals are generally referred to as dynamic seals and the usual configuration is an O-ring. Testing of seals under dynamic conditions is generally required to verify that seal materials are compatible with fuels of varying composition. This report describes a device that is designed for testing dynamic seals that come in contact with liquid fuels, although the device described herein can also be used for testing seals in the presence of other liquids and for applications other than turbojets.

<u>CAUTION 1:</u> *The device described herein is considered to be a* ***developmental research tool*** *and not a commercial test apparatus. While reasonable efforts have been exerted to develop a user friendly and safe device, caution must be exercised while operating the device. Several <u>surfaces are hot</u> enough to cause skin burns if touched and there are several <u>moving parts</u> that one must avoid contact. The system is designed to be loaded with small amounts of <u>fuel</u> and upon failure of a test seal, fuel will leak into a catch basin or beaker. Therefore, this device needs to be well ventilated and placed away from potential ignition sources. Fire extinguishing equipment should be placed near the test device.*

2.0 DESCRIPTION OF TEST DEVICE

A testing device for evaluating materials (elastomers) used in the manufacture of circular shaft seals (O-ring) is described herein. The device simulates sealing conditions normally employed for sealing a shaft that reciprocates in its axial direction.

2.1 Mechanical and Fluid Components

Figure 1 shows a cross section drawing of the principal component of the test rig. A stainless steel shaft with test O-rings, machined to highly precise dimensions (± 0.005 inch), is reciprocated in a heated aluminum block containing a precision bore also machined to highly precise dimensions. A small cavity at each end of the aluminum block, formed within the end caps, collects fuel that leaks past the O-ring under test. The "primary seal" is the seal under test and the function of the "secondary seal" is to prevent fuel from leaking past the fuel collection cavity. The end cap is also sealed against the body via an O-ring seal (AS-568-116).

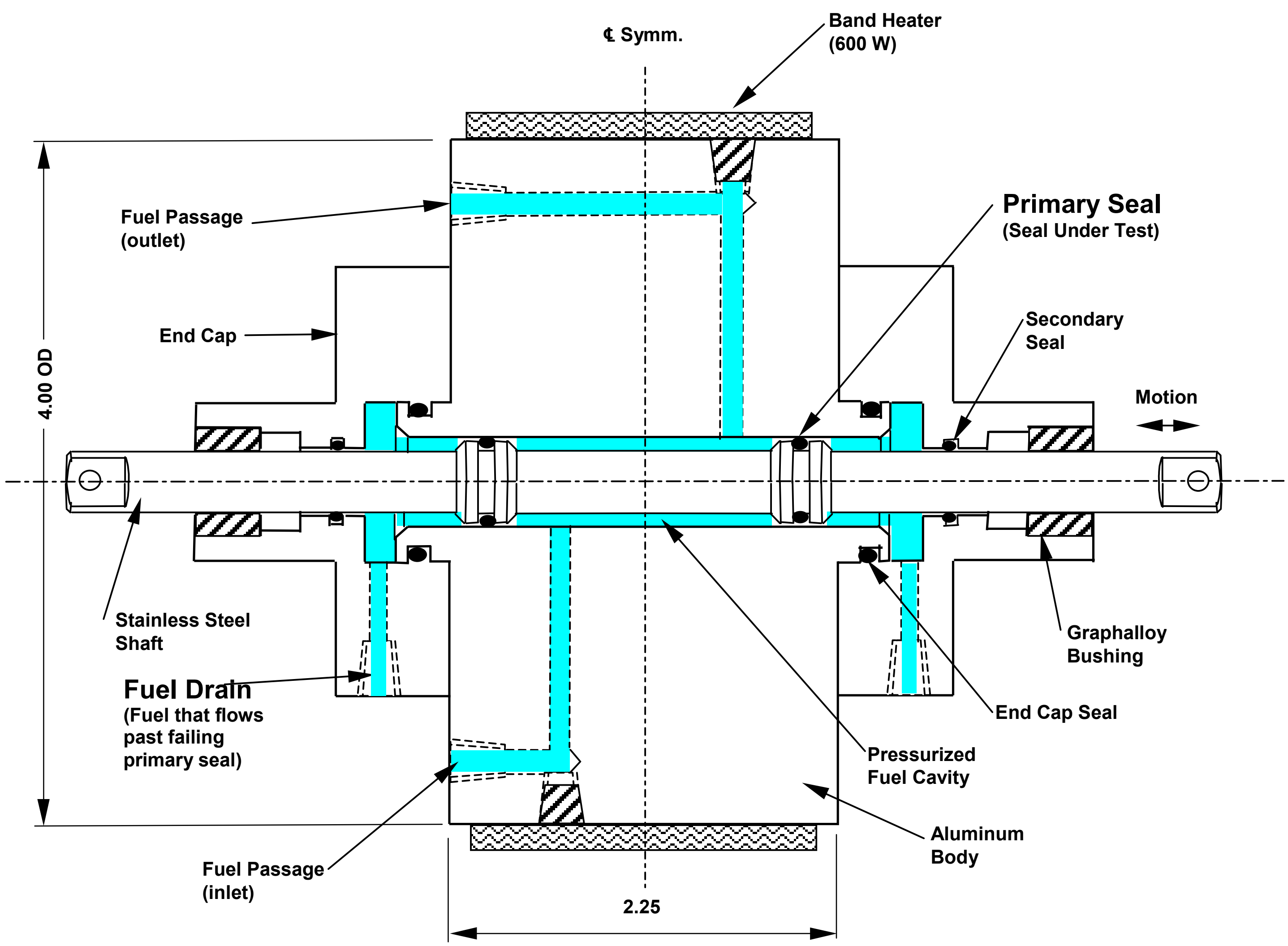


Figure 1. Schematic of a "spool valve" assembly used for determining leakage rate of a seal under test (primary seal).

Elastomeric O-rings to be tested (size AS-568-012) are installed on the shaft; two are required, one each on the ends of the shaft. Jet fuel of varying composition is pumped into the central cavity defined by the volume between the two shaft seals and the cylindrical region between the shaft and bore wall. The spool is translated ± 3/16 inch at a frequency of 12 strokes per minute. Assuming a sinusoidal displacement, the peak velocity is approximately 14 inches per second.

<u>CAUTION 2:</u> *The unit is supplied with Buna N seals. Seals with different composition will need to be installed based upon research needs. The shaft O-ring groves and end cap shaft O-ring grooves are designed in accordance with SAE-ARP-1233. The – 012 size O-ring is required (0.070" cross section x 0.364" ID). It is recommended that the end cap O-rings be replaced with Viton seals or equivalent. The larger diameter end cap seal located on the main body is a – 116 size.*

A 600 W band heater under the control of a Watlow Series 93 microprocessor-based temperature controller can control the fuel temperature within the central cavity to the desired test temperature, which should not exceed 300 °F. Type T thermocouples are located in the valve body to within approximately 1/8 inch of the spool O-rings. (Not shown in Figure 1.) This close proximity promotes more accurate measurement of the actual temperature of the O-ring. One thermocouple is located over each O-ring. The cavity temperature is controlled by measurements from only one of the thermocouples, but either one can be selected. The measured temperature from both locations is always monitored and displayed.

The heated and insulated block and shaft is supported on a rigid aluminum frame structure. The force needed to move the shaft is directed in the shaft's axial direction and precisely collinear on the axial centerline of the shaft. This is accomplished by a cross-head assembly incorporating two linear bearings. See Figures 2 and 3. The force is supplied by a 12 rpm, 3/4 horsepower gear-motor connected to a bell-crank mechanism. The shaft horizontal displacement is set to ± 3/16 inch. The stroke can be adjusted a small amount by setting the radial distance of the bell-crank pin. The stroke should not be more than ± 1/4 inch because the shaft must keep its stroke within the allowable bore length.

Figure 2. Face on view of Dynamic Seal Test Rig. ***Axial motion of the shaft within the heated block is supplied by a bell crank mechanism and cross-head assembly.***

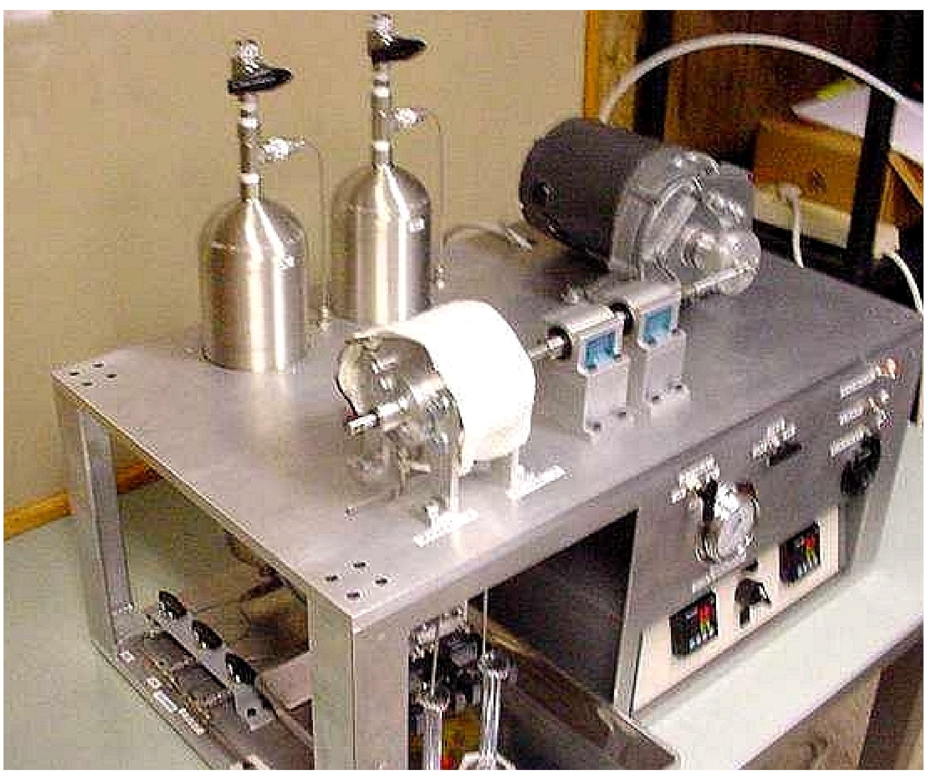


Figure 3. View of top surface layout of Dynamic Seal Test Rig. ***Two fuel reservoirs are available for testing with two different fuels.***

A unique feature of the rig is its ability to switch fuels during a test run. The test can start with one particular fuel that is brought into contact with the O-ring seals and then switched to a second fuel with a different composition. This simulates a common situation that occurs in the field for which there is little known about the frequent changes of fuel composition on elastomers. To accommodate this feature, two reservoirs and associated valves are required. The switching is accomplished manually (i.e. not automated).

A line diagram of the entire system is shown in Figure 4. Labeling of valves and components on the test rig correspond to the nomenclature used in the schematic. Fuel is pumped into the heated block by pressurizing the fuel in the reservoirs with nitrogen. The nitrogen pressure is displayed by the pressure gauge on the front panel. A safety relief valve, V8, located on the top surface of the rig behind the motor is set at approximately 150 psi.

CAUTION 3: *The safety relief valve located immediately behind the electric motor on the top surface will hiss loudly when nitrogen gas is being released. This will normally occur when the regulator on the nitrogen gas bottle is set too high. Upon this event, the nitrogen regulator must be set to a lower pressure immediately.*

Selector valve V1 will direct nitrogen gas into reservoir A or B and selector valve V2 will direct fuel into the test rig. These valves are clearly identified on the front panel of the rig with "N2" for valve V1 and "Fuel" for V2. Valve V3 is used to purge fuel through the test rig and valves V4 and V5 are for draining fuel from the reservoirs. These valves are clearly marked and are located on the lower right hand side of the rig. Physically, all three valves are connected together on their downstream side to a common drain line. Valves V6 and V7 are ball valves to be opened when filling the fuel reservoirs. A suggested way to fill the reservoirs is to use a "squeeze bottle" or insert a small tube through the valve through which to pump the fluid.

Fuel leaking past the seals under test is captured in two 10 ml graduated cylinders located just below the heated block. If more than 10 ml of fuel is captured in either cylinder, a photoelectric sensor will sense this overfill condition and initiate a shutdown sequence whereby the motor that provides spool motion is stopped and the heaters are turned off. The power to the hour meter is also shut off, indicating how long the unit was running prior to shutdown.

CAUTION 4: *The 10 ml graduated cylinders should be placed in a spill containment of volume greater than the fuel contained in the selected reservoir used during a test, e.g., if reservoir A contains 200 ml of fuel and it is the operating reservoir, then a spill basin of greater than 200 ml is required.) This is to prevent spillage of fuel if that fuel overfills the graduated cylinders.*

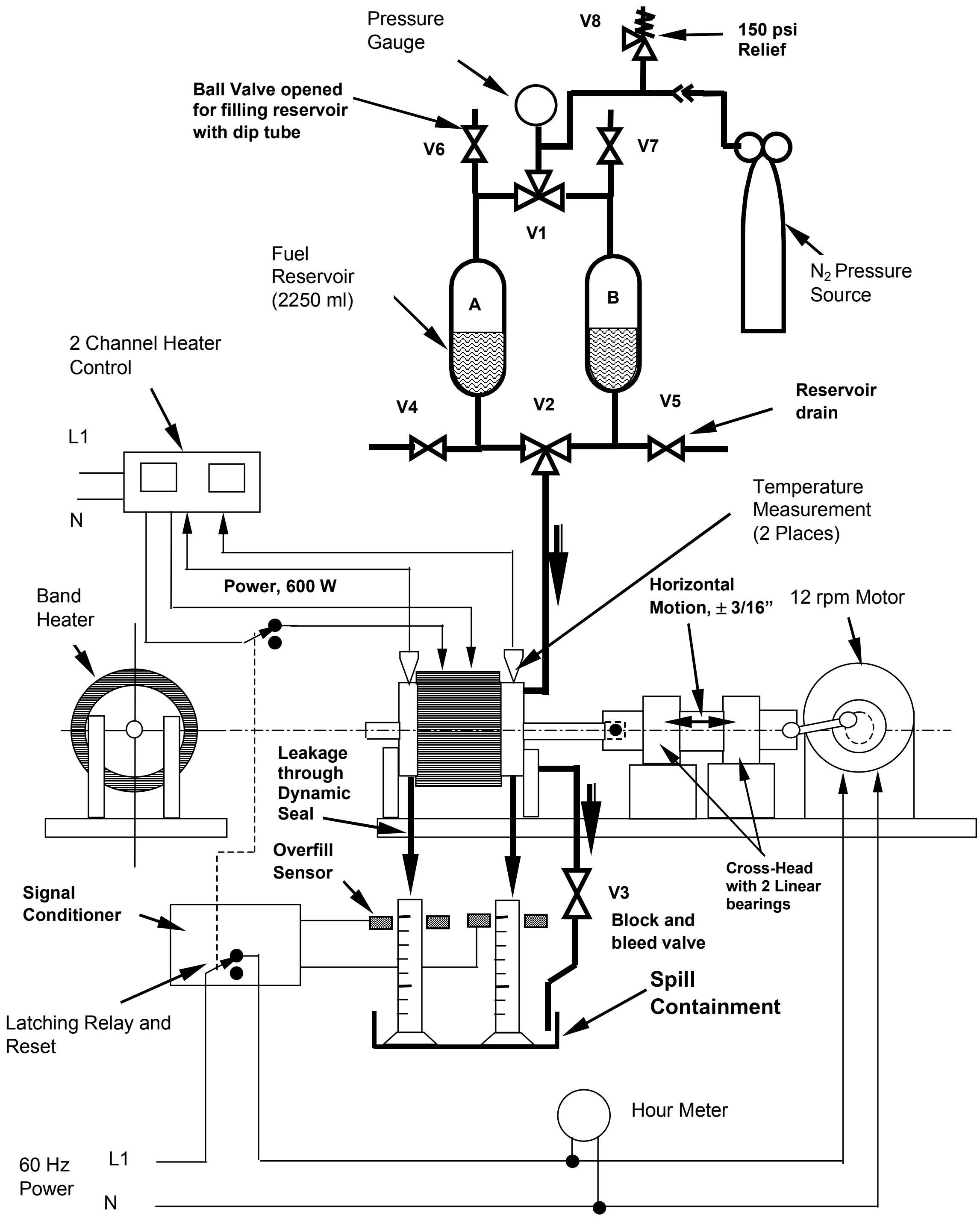


Figure 4. Overall system schematic of the Dynamic Seal Test Rig

2.2 Electrical Circuits

A systems level block diagram of the electronic components is shown in Figure 5. The dynamic test rig contains a heater control unit (Southwest Heater and Controls, Serial No. 11790), photoelectric level sensors and signal conditioners (Banner), and interface board with relay logic, a motor unit (Dayton model 5K934), a pushbutton resettable hour meter (Cramer Model 636X) and a 600 watt two-piece band heater (Omega MBH-4020600T). Setup and operation of the photoelectric sensors and the HCU is found in the Appendix A.

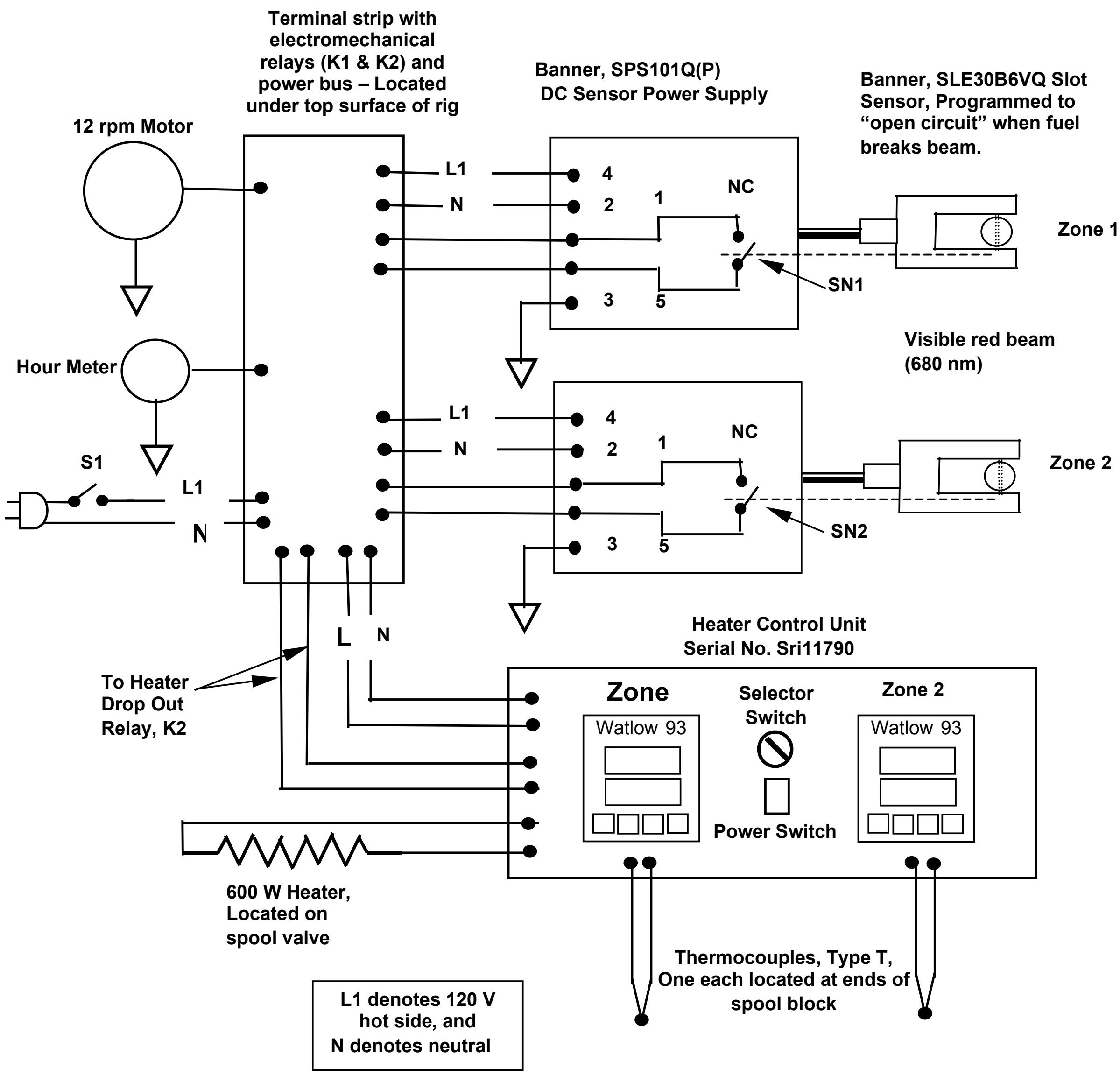


Figure 5. Systems Level Electronic Block Diagram

Circuit details for the heater control unit is shown in Figure 6. The unit as received from Southwest Heater and Controls was modified by the installation of a BNC plug in one leg of the solid state relay. This modification is needed to override control of the heater power from an external source.

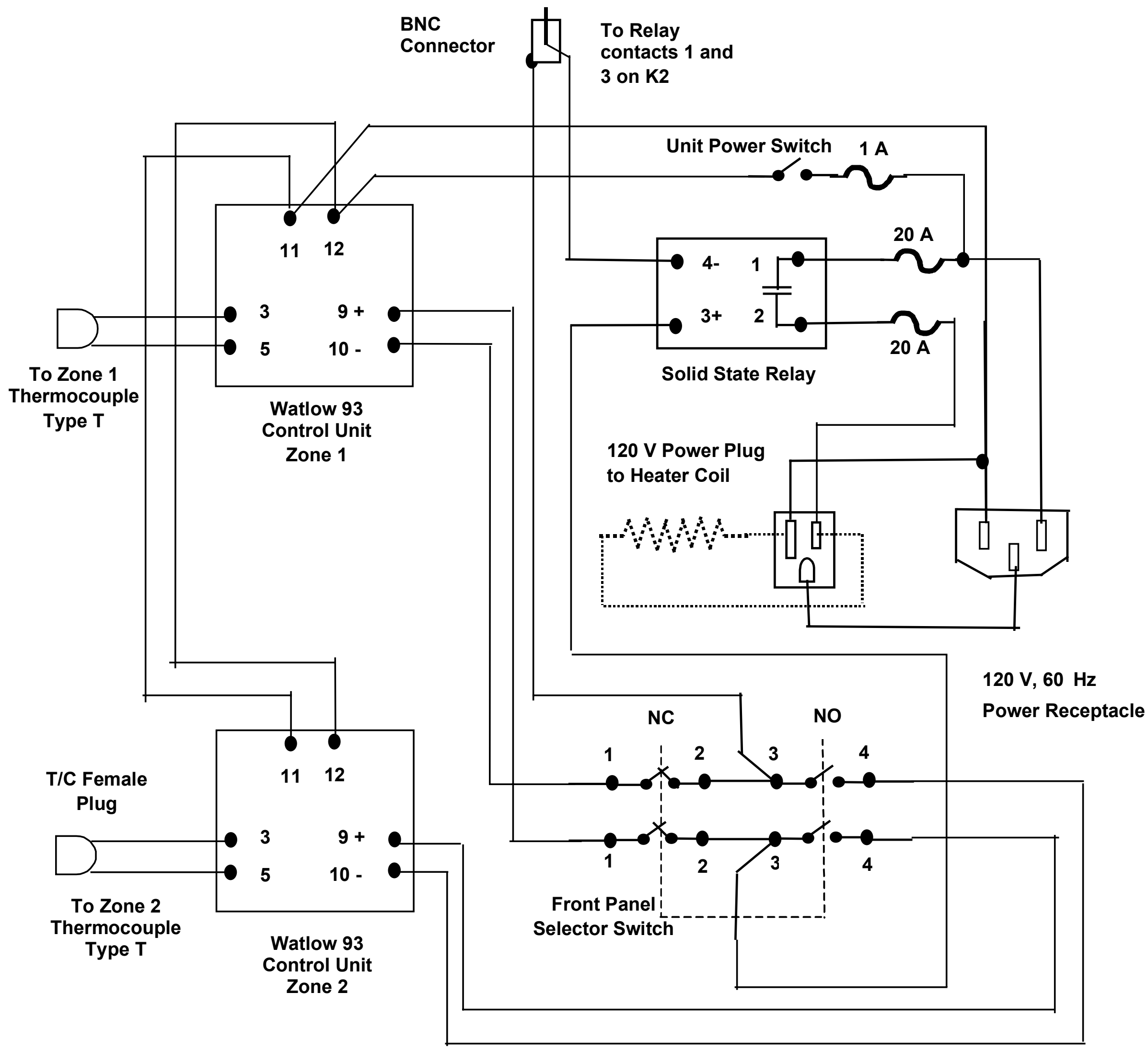


Figure 6. Circuit Details for Heater Control Unit (HCU)

Pin numbers for the major components are noted in Figure 6, which include the heater control modules (Watlow Series 93), front panel switch, solid state relay, and power plugs (square shape plug goes to the heater element and the rectangular shape plug goes to 60 Hz, 120 volt supply power). Both control units are always active and display temperature for Zone 1 and Zone 2 of the heated block; however only one of these units control the heater depending on the position of the selector switch. This provides some level of redundancy for the system, because if one of the control units fail, the other unit can still control the system. Of course, only one temperature readout will be available, but the heated body is nearly isothermal and the temperature of the heated block does not deviate much from end to end of the body. Setup and operation of the Watlow Units is contained in the Appendix A.

Figure 7 shows the electrical interconnection and relationships of the electronic modules and an understanding of these interconnections is important for proper operation of the dynamic test rig.

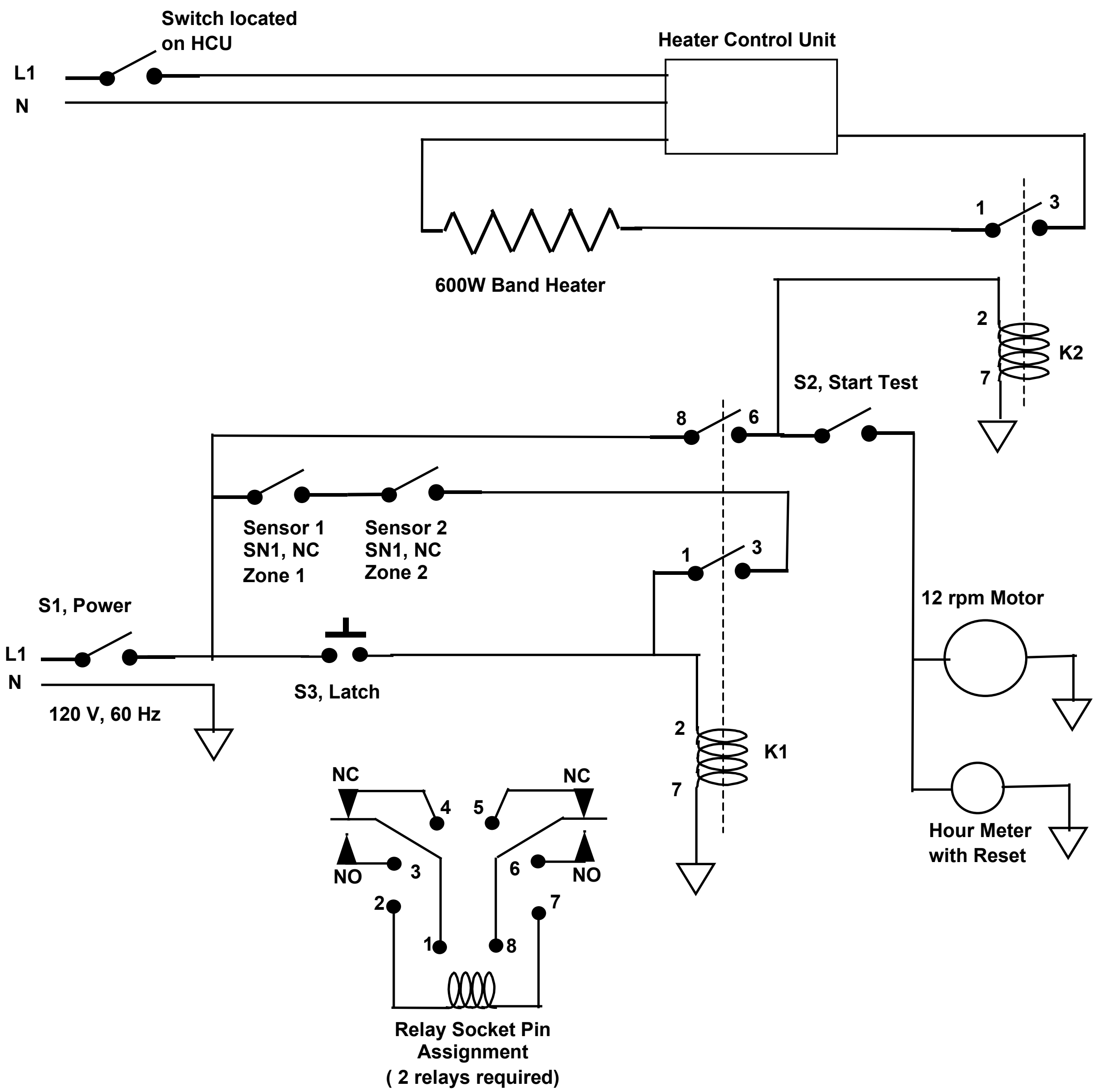


Figure 7. Electrical Interconnection of System Control Components and Relays

Switches labeled "Start, Latch, and Power" are located on the front panel of the unit, and the power switch for the heater and its control is located on the heater control unit. After proper setup of the level sensors (SN1 and SN2) and upon proper loading of fuel, starting of the unit proceeds as follows: Turn all power switches to on position (front panel and heater control unit). Depress the Latch switch to energize coil K1 (A light next to the switch will illuminate to show that the circuit is armed). At this point, SN1 and SN2 are active and power is being supplied to the heater control unit and heater through activation of K2. Set the heater controls to a desired temperature (generally greater than 150 °F but not to exceed 300 °F). Turn the selector switch to either Zone 1 or Zone 2 for the chosen zone of active control. Heat up generally occurs within 15 minutes and it is recommended to start a test as the temperature passes through 150 F. Starting of a test is initiated by switching the Start switch to the on position. (A light will turn on as this switch is toggled.) At this point the motor will be activated and the oscillatory motion of the shaft will be initiated. Also, the hour meter will be activated.

The test will run unattended until the liquid level sensor (SN1 or SN2) is activated (breaking power to K1 and K2). A test can also be terminated by turning off the power switch or start switch. <u>*Caution*</u> *should be exercised if only the start switch is turned off because power will not be cut off to the heater and only the motor and hour meter are halted.* Further testing can be commenced only after depressing the Latch switch to rearm the circuit.

3.0 INSTALLATION OF TEST RIG

Uncrate unit and remove packing material. Remove graduated cylinders that are packaged separately. Inspect for damage that may have occurred during shipment. Look for loose parts, bent parts, or broken parts. Notify shipper if damage is found.

The unit fits into a cubical volume of approximately 18" wide by 30" long by 25" high. The dry weight is approximately 139 pounds. Four rubber pads are attached to the bottom of the unit to prevent sliding and to accommodate surfaces that are somewhat rough and not level. This unit should be placed in a ventilated area to prevent the accumulation of fuel vapors.

Install valve V6 on top of reservoir A and install valve V7 on top of reservoir B. Also, install the pressure relief valve, V8, to the N2 port located just behind the electric motor.

A 1/4" tube fitting located just above the relief valve, V8, is provided for connection to a pressurized nitrogen bottle. The nitrogen bottle must be equipped with a regulator that can safely maintain a nitrogen pressure of not to exceed 150 psi. Pressurized nitrogen is supplied to the upper region of the fuel reservoirs and used to pump fuel into the dynamic test rig.

Flexible tubing should be attached to the 1/8" drain line found on the front of the unit on the lower left-hand corner. This flexible tubing will be needed when draining or venting fluid from the unit and its reservoirs.

The unit requires 120 volt, 60 Hz AC power with and estimated maximum current draw of 15 amps. The heater is fused for 20 amps and the heater control unit is fused for 1 amp. These fuses are located inside the heater control unit.

4.0 OPERATING INSTRUCTIONS

O-rings are normally tested until failure, which is loosely defined as excessive leakage of liquid. Liquid that seeps past the shaft seals is collected in the receiving glass cylinders. By quantifying the volume of liquid collected, the seal performance may be characterized in terms of leak rate, i.e. ml/hour, at various times during the test cycle or one may record the elapse time for some type of catastrophic failure of the O-ring.

The following instructions provide guidance for installation of test seals and operating the rig.

4.1 Installation of O-rings

Prior to the initiation of a test, one will need to insert test seals on the shaft. Therefore, the shaft must be extracted from the body. This is accomplished by removing the chain link that connects the test shaft to the 0.75-inch diameter crosshead shaft. This will decouple the shaft from the crosshead shaft. For ease of reassembly, it is recommended that the motor not be rotated once the link is removed so as to maintain proper stroking (displacement) of the O-ring shaft. Next, remove four 5/16 inch bolts that secure the left hand (viewed facing the front panel) end cap. See Figure 8.

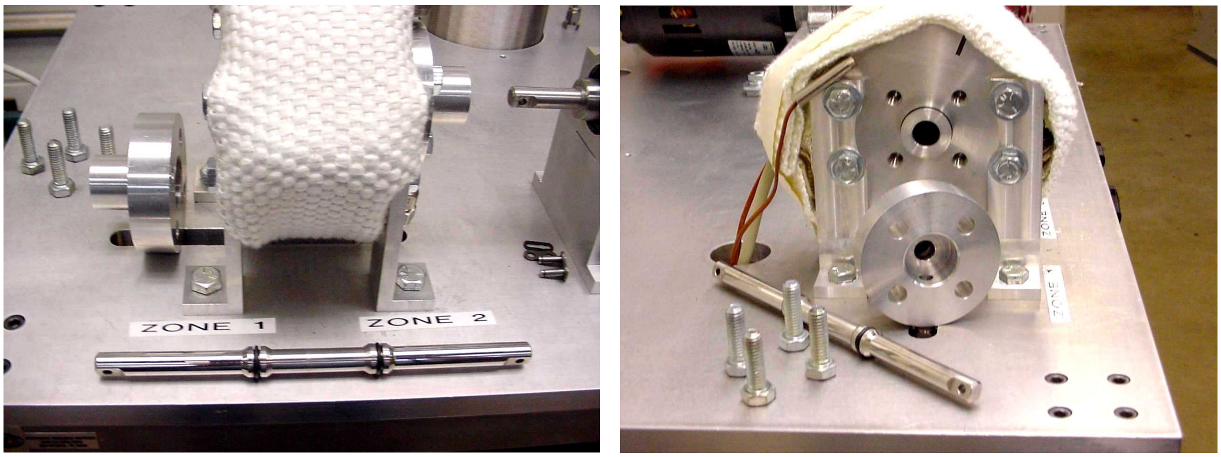


Figure 8. Several views showing left end cap and shaft removed. *Note the chain link in left photo that has been removed to decouple the crosshead shaft and the O-ring seal shaft.*

Once the O-ringed shaft has been pulled out, one may carefully remove the O-rings, avoiding the unnecessary introduction of scratches or cuts. Normally, O-rings that are removed will be further examined under a magnifying glass to observe damage caused during testing. The end cap also contains one internal O-ring and a graphalloy bushing (Type 117-6-111). The graphalloy bushing is expected to exhibit exceptionally long life, but the O-ring may need to be replaced from time to time. It is recommended that a Viton O-ring be used. Also shown in the right hand photo of Figure 8, one may see the O-ring that is installed on the aluminum body. It is recommenced that a Viton O-ring be used here. Under normal test operations, the only seals that will be routinely replaced are the O-rings on the shaft.

Upon installation of test seals on the stainless steel shaft, the inverse process is used to reassemble the unit. The shaft is carefully inserted into the body to avoid cutting the O-ring as it is inserted. A chamfer is machined at the end of the bore to smooth the corner, but care should be exercised during the insertion process. The shaft is pushed all the way through until it stops against the crosshead shaft. The chain link can now be reinstalled. If the stroke displacement requires a change, one may adjust the pin position on the bellcrank.

4.2 Location of Controls and Sensors

On the front panel (See Figure 2), one will find:

- Three switches, labeled Power, Start, and Latch with indicators located nearby,
- A selector valve marked N2,
- A selector valve marked Fuel,
- A pressure gauge with 200 psi full scale,
- An Hour meter with a reset button,
- The heater control unit with a power switch, two controllers, marked Zone 1 and Zone 2, and a selector switch that will point to the Zone 1 or Zone 2 controller. A 1-amp fuse receptacle is also on the unit. The controllers provide digital temperature readout and set point.

There is an opening on the lower left side that contains two vertical drain tubes that originate from the end caps of the heated block located on the top surface of the unit. Also, a vertical bracket supports two sensors that look like C clamps. These sensors contain push buttons on their backside, which are important for setting up the operation of these sensors. Under normal operation, a 10 mL graduated cylinder is placed within the c-clamp region such that a red beam will cross the cylinder.

4.3 Operation

The general steps needed to operate the rig and to set up control functions are outlined in Table 1. The sequence as shown in the table may be altered somewhat, especially after some experience is gained with the system. However, it is important to be always aware that pressurized fuel is present and in contact with hot surfaces.

Table 1. Setup and Run Procedures		
Step	**Action/Purpose**	**Notes**
1	Check unit for safety and proper ventilation	
2	Check unit for leaks or obvious damage	
3	Close valves V6 and V7	Located on top of Reservoir A and B
4	Close Valves V3,V4, and V5	Located on the open end of the left side
	FUEL LOADING OF RESERVOIR A	It is recommended that normal grounding practices be followed and no ignition sources should be present.
5	Switch V1 and V2 to B	This ensures no contamination of A by B
6	Open V6	
7	Insert a “fill tube” through ball valve V6, allow for venting	Other safe fill methods can be used
8	Inject fuel into Reservoir A, not to exceed 2000 ml	Record amount and type of fuel loaded.
9	Remove fill tube and Close V6	
	FUEL LOADING OF RESERVOIR B	The rig can be run with either or both reservoirs loaded.
10	Switch V1 and V2 to A	This ensures no contamination of B by A
11	Open V7	
12	Insert a “fill tube” through ball valve V7, allow for venting	
13	Inject fuel into Reservoir B, not to exceed 2000 ml	Record amount and type of fuel loaded.
14	Remove fill tube and Close V7	
	PRESSURIZATION	Pressurized nitrogen gas is injected over the fuel to suppress vaporization and provide fuel flow through the rig.
15	Set pressure regulator on nitrogen bottle to 150 psi. Note pressure reading on front gauge.	If pressure exceeds about 170 psi, a loud hiss will radiate from the pressure relief valve, V8. Immediately back down the pressure on the regulator.
16	Switch V1 and V2 to A, note pressure reading on front gauge.	Pressure will rise to the set pressure of the regulator.
17	Switch V1 and V2 to B, note pressure reading on front gauge.	Pressure will rise to the set pressure of the regulator.
	PURGING	Necessary to purge test fuel through the rig prior to test initiation.
18	Place a collection container at the end of the vent line.	The vent line is a tube on the left lower corner of the unit.
19	Switch V1and V2 to a selected reservoir (A or B)	
20	Open V3 slowly and look for fuel to flow out of the vent line	
21	Collect at least 25 ml and safely dispose of this fuel.	
22	Close V3	
	POWER	
24	Turn “Power” switch on. (An orange lamp will illuminate.)	Unit should be plugged into 60 hz, 120 V power source that can supply 15 amps. When power switch is on, power is supplied to HCU and sensor units. There is a white power strip located on the terminal chassis under the top plate; switch on.

Table 1. Setup and Run Procedures		
Step	**Action/Purpose**	**Notes**
25	Power switch on Heater Control Unit (HCU) *may* be turned on at this point if the controllers for Zone 1 and Zone 2 are set below 100 °F.	Prior to the initiation of a test, the controllers will be set to the desired test temperature (See step 34).
	SETUP OF LEVEL SENSORS	
	Details for setting the logic and calibration of the overfill sensors, SN1 and SN2 are found in the Appendix and should be consulted for specifics not covered in this Table. Also, these sensors have been setup by SwRI to open circuit when fuel within a glass cylinder absorbs energy from the 2 mm visible red beam that passed diametrically through the cylinder.	
26	Fill one 10 ml graduated cylinder to the top with test fuel.	Used to set up overflow shutdown limit
27	Depress "Latch" switch. (Red light will illuminate.)	This will arm the sensors.
28	Place an empty graduated cylinder in the slot ("C" shaped region) of Sensor 1 that is located under Zone 1 of the heated block (left hand sensor) and press the "teach button."	The "teach button" is located on the rear side of the sensor.
29	Replace empty cylinder with the fuel filled cylinder and press the teach button. (The red beam must be shooting through the fuel.)	If at any time the sensor circuit triggers, the latch lamp will go out and the latch switch must be pressed again to continue the setup.
30	Insert an empty cylinder and make sure the latch lamp is on.	
31	Insert filled cylinder; sensor should trigger and latch lamp will go out.	
32	Repeat steps 26 through 31 for sensor SN2 located under Zone 2 of the heated block (right hand side)..	
	OPERATION OF HEATER CONTROLS	
	Details for setting up the heater controls are found in a manual in the Appendix for the Watlow Series 93 controller. The controller has been initially setup by SwRI for reasonably fast and accurate (minimal offset) operation.	
33	If the unit is on (see step 25), two sets of numbers should be displayed on each of the controllers marked Zone 1 and Zone 2. The upper display indicates the actual temperature and the lower display indicates the set point temperature.	
34	Set point should normally indicate a value a bit above room temp. (approx. 100°F). To increase set point, press up-arrow button once for single digit increase, hold down for rapid digit increase**. *It is not recommended to exceed a set point temp. of 300°F,*** *but this could be exceeded somewhat depending upon the seal application.*	Prior to shutting down the system, one should reduce the set point temp. to approximately 100°F. (See Step 35.) This will prevent excessive temperature buildup when the unit is first turned on and at the same time, control function can be checked by noting that the block temperature is approaching the set point temperature.

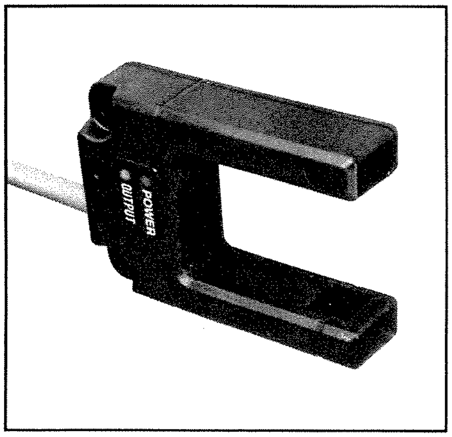
Table 1. Setup and Run Procedures		
Step	**Action/Purpose**	**Notes**
35	At the conclusion of a test, it is recommended that the set point be reduced to approximately 100 °F by pressing the down-arrow on the controller face.	
	INITIATION OF TEST	
	A test plan should be developed to identify type of fuels to be included in the test, operating temperature, and a failure criteria should be identified (such as a maximum acceptable leak rate).	There is no provision for automated data acquisition, so all data will need to be recorded manually. One may wish to weigh the cylinders a the initiation of the test and periodically during a test.
36	The following setup sequence will normally be accomplished prior to initiation of a test. (1) Place the two graduated cylinders under the drain tubes, (2) bring the nitrogen pressure to 100 psig., (3) select fuel reservoir, A or B, (4) set N2 selector valve to correspond to selected fuel, A or B, (5) Select Zone 1 or Zone 2 on the heater controller, (6) Depress reset button on the hour clock to bring the clock to zero hours, (7) **Depress the Latch switch**, (8) set desired test temperature on the selected Zone controller (300 F or less).	Make sure selected fuel is purged through the system.
37	When the measured temperature reaches 80 to 90 % of the selected test temperature, flip the "Test" switch to on.	Test lamp will illuminate, and spool should start to reciprocate.
38	Unit will run unattended until sufficient fuel is collected in either graduated cylinder to activate the level switch, at which time the system will shut down.	Shutdown will cause motor to stop, hour meter to stop, and heater will be turned off. ***CAUTION**. There is no automatic fuel shut off valve, so fuel under pressure can continue to leak through a failed seal. This fuel will overflow the cylinder and run into spill containment. Spill containment with sufficient volume should be used such that all fuel in the reservoir can't overflow containment.*
39	Bring nitrogen pressure to zero (shut off nitrogen regulator and vent fuel if necessary). Record time of failure.	
	POST RUN ACTIVITIES	
40	If test is manually stopped (turn Power switch to off) or stopped by overfill limit action, several actions would normally be taken. (1) Bleed fuel from system by utilizing the nitrogen overpressure in the reservoir (open valves V3, V4, or V5), (2) Bring nitrogen pressure to zero (3) Dispose of excess fuel in containment pan if present,	

APPENDIX A
COMPONENT MANUALS

SLE30 *Expert*™ Series Teach-Mode Slot Sensor

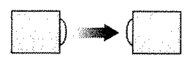
Self-contained opposed-mode sensor pair with Teach Mode

the photoelectric specialist

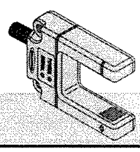


SLE30 *Expert* Series Slot Sensor Features

- An easy-to-use, self-contained opposed-mode sensor pair in a rugged U-shaped housing
- Easy push-button programming automatically adjusts sensitivity to optimal setting
- Dynamic TEACH programming option provides on-the-fly convenience and minimizes the effects of web flutter
- Separate TEACH input allows remote programming by an external device, such as a switch or a process controller
- Easy output programming eliminates the need for Light or Dark Operate selection
- Choose fast 500 microsecond or 150 microsecond output response
- 2 mm effective beam
- Visible red beam
- Molded-in beam guides simplify mounting and beam placement
- 30 mm slot width for a wide variety of sensing applications
- Applications include label detection, hole detection, edge guiding and counting
- 10 to 30V dc operation
- Bipolar PNP/NPN outputs
- Choose integral, unterminated cable or QD models



Visible red, 680 nm



SLE30 *Expert* Series Slot Sensor Models

<table>
<tr><th>Models</th><th>Slot Width</th><th>Cable*</th><th>Supply Voltage</th><th>Output Type</th><th>Response</th><th>Repeatability</th></tr>
<tr><td>SLE30B6V</td><td rowspan="4">30 mm (1.2")</td><td>2 m (6.5') 5-wire cable</td><td rowspan="4">10-30V dc</td><td rowspan="4">Bipolar NPN (sinking) and PNP (sourcing)</td><td rowspan="2">500 microseconds</td><td rowspan="2">100 microseconds</td></tr>
<tr><td>SLE30B6VQ</td><td>5-Pin Euro-style QD</td></tr>
<tr><td>SLE30B6VY</td><td>2 m (6.5') 5-wire cable</td><td rowspan="2">150 microseconds</td><td rowspan="2">75 microseconds</td></tr>
<tr><td>SLE30B6VYQ</td><td>5-Pin Euro-style QD</td></tr>
</table>

*NOTES: 1) 9 m (30') cables are available by adding suffix **"W/30"** to the model number of the cabled version (e.g., **SLE30B6V W/30**).
2) A model with a QD connector requires an accessory mating cable. See page 5.

SLE30 *Expert*™ Series Slot Sensor

SLE30 *Expert* Series Slot Sensor Overview

The SLE30 Series Slot Sensor (sometimes called a "Fork Sensor") comprises an opposed-mode emitter and its receiver inside a single convenient housing. Opposed-mode sensing is very reliable, and the single self-contained housing provides easy installation, with no sensor alignment required. In addition, the molded-in arrow on the emitter portion of the housing and the slotted design on the receiver portion of the housing show at a glance the position of the beam, simplifying installation placement.

Expert series sensors feature easy-to-use push-button programming, performed in TEACH mode. TEACH-mode programming may be performed using either the push button, or remotely, using a remote switch or process controller. The programming determines whether the sensor outputs will conduct in light or dark conditions, and defines the light and dark conditions for the sensor in each application. The remote switch also may be used to disable the programming push button for security.

The Dynamic TEACH option provides a means for teaching a series of conditions; the SLE30 monitors the sensing events and automatically sets the threshold between light and dark conditions.

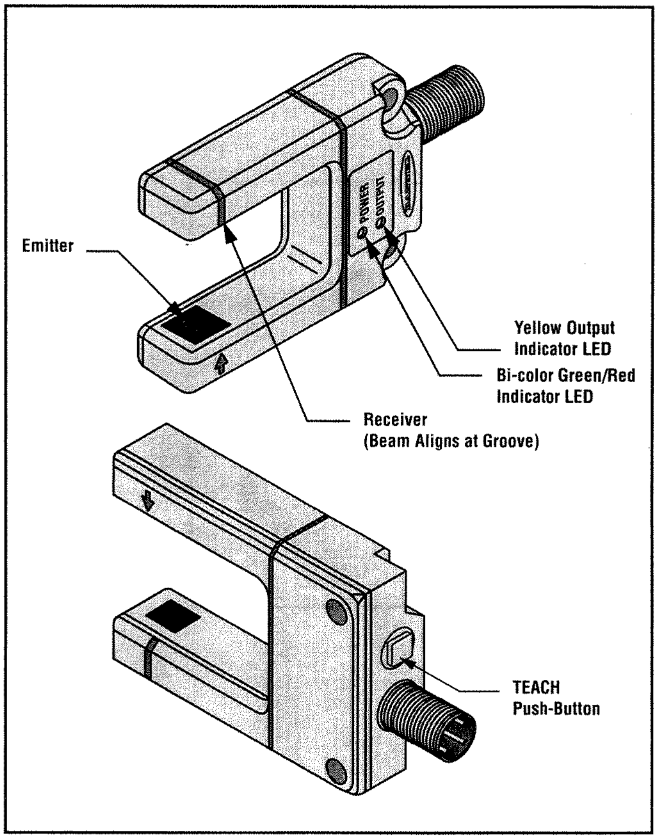


Figure 1. SLE30 *Expert* Series features

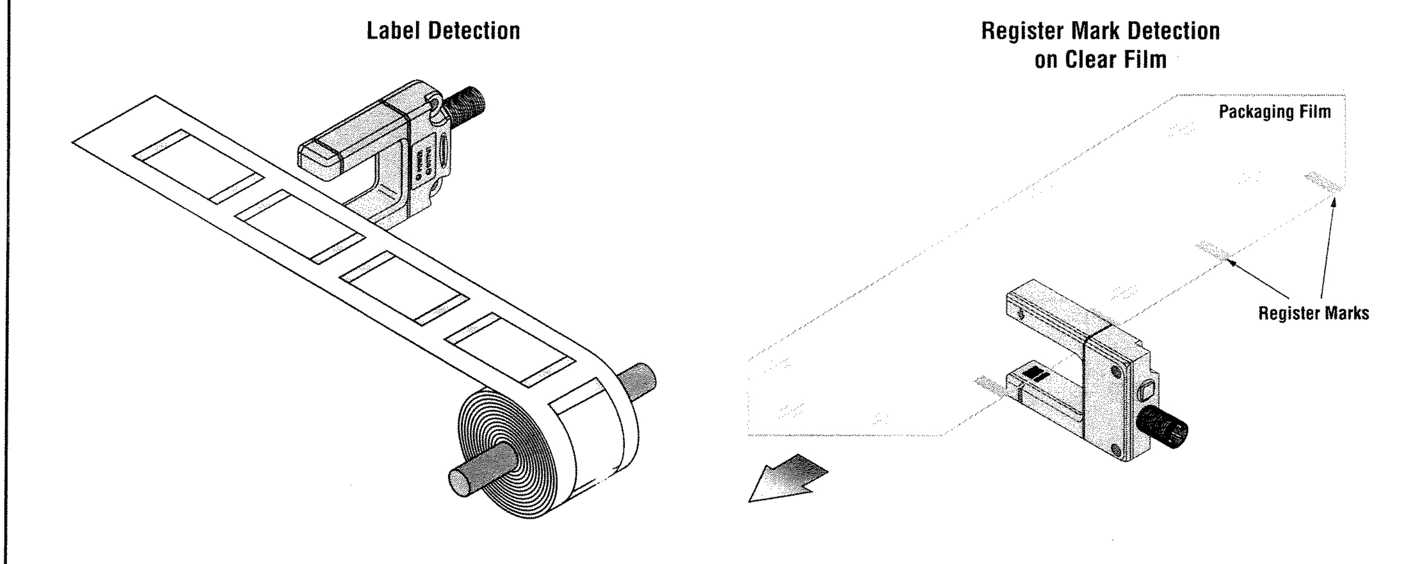


Figure 2. SLE30 *Expert* Series typical applications

Using the SLE30 *Expert* Series Slot Sensor

RUN Mode

Normal operation of the SLE30 *Expert* is called RUN mode. The two LED indicators (bi-color Green/Red and Yellow) operate as follows in RUN Mode:

Green (RUN Mode): ON steady whenever power is applied
Flashes as received light level approaches the switching threshold (stability indicator. The stability indicator signals when maintenance or reprogramming is needed during RUN mode.)

Yellow (Output): ON when the outputs are energized (conducting)
OFF when the outputs are de-energized (not conducting)

If contrast is marginal, the bi-color indicator will flash green (to indicate instability). Reprogramming the sensor, or cleaning the sensor lenses may solve a problem with stability.

TEACH Mode

Programming of the SLE30 Expert – setting the sensitivity and selecting output ON and OFF conditions – is performed in TEACH Mode. The SLE30 provides two methods for programming: Static TEACH and Dynamic TEACH. Static TEACH is used in all programming situations to set up the sensor's output ON and output OFF conditions. Sensitivity is then set using either the Static method described below or the Dynamic method on page 4.

Both Static TEACH and Dynamic TEACH may be performed using either the sensor's TEACH push button or the Remote TEACH line (see page 6).

Static TEACH

Determining the Output ON and OFF Conditions
The two sensing conditions may be presented in either order. The condition presented first is the condition for which the outputs will energize (the "Output ON" target).

Setting Sensitivity
Sensitivity is automatically set (and optimized) when teaching the sensor the ON and OFF conditions. When the push button is clicked, the sensor samples each sensing condition and registers it into memory. After the second sensing condition is registered, the SLE30 *Expert* automatically sets the sensitivity to the optimum value for the application, and then returns to RUN mode.

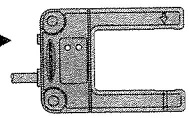
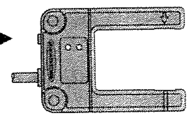
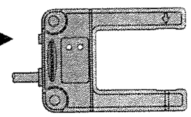
The two LED indicators (bi-color Green/Red and Yellow) operate as follows in TEACH Mode:

Red (TEACH Mode): Lights when the sensor "sees" its modulated light source; pulse rate is proportional to the received light signal strength during TEACH programming

Yellow (Output): ON to indicate TEACH output ON condition
OFF to indicate TEACH output OFF condition

The Signal Strength indicator is Banner's exclusive AID™ (Alignment Indicating Device). Its pulse rate increases as the received light signal strength increases (during programming). This feature simplifies accurate alignment during TEACH mode, and gives a relative indication of sensing contrast between the light and dark conditions.

Static TEACH Sequence

Push Button			Resulting Indicator Status
Press and hold until the bi-color (green/red) indicator begins to flash red, or turns OFF.	**Push and Hold** **≥ 2 Seconds** 		**Yellow:** ON **Red:** Pulses to indicate relative received signal strength.
TEACH Condition #1 (Output ON state) Present the first sensing condition to the sensor and single-click.†	**Single-Click** 	**Sensing Condition #1 (Output ON State)**	**Yellow:** OFF **Red:** Pulses to indicate relative received signal strength.
TEACH Condition #2 (Output OFF state) Present the second sensing condition to the sensor and single-click.	**Single-Click** 	**Sensing Condition #2 (Output OFF State)**	If contrast is acceptable, the sensor returns to RUN mode; otherwise it will return to TEACH Condition #1. **Green:** ON (or flashes if signal is close to the switching threshold). **Yellow:** OFF, until the sensing condition changes.

†NOTE: The sensor will return to RUN mode if the first TEACH condition is not registered within 90 seconds. TEACH mode may be cancelled before either condition #1 or #2 by holding the push button depressed for ≥ 2 seconds.

A Note About the "Clicks": Clicks are meant to be pressed firmly, then quickly released. Indicators go ON or OFF after a brief delay; do not wait until LEDs change status before releasing push button. (If push button is pressed for 2 seconds or longer, sensor will automatically return to RUN mode.)

Dynamic TEACH

Dynamic TEACH is a method of setting the sensor's sensitivity while the object to be sensed is in motion. Typical applications are label sensing and small parts detection. In a label application, web flutter may change the amount of light passing through the label and its backing material. Dynamic TEACH will sense this variation and adjust the sensitivity to account for it.

In a small parts detection application, alignment of the object to the sensor's effective beam may make Static TEACH difficult. In this case, Dynamic TEACH will allow you to pass individual or multiple parts through the beam; the sensor then will detect them and set the sensitivity automatically.

Determining the Output ON and OFF Conditions

Dynamic TEACH is used for optimizing the sensor's sensitivity and will not configure the output ON and OFF conditions. A Static TEACH must be [illegible]ed first to change the output ON and OFF conditions, if needed. If the outputs are co[illegible]ured properly for your installation, Dynamic TEACH may be performed as needed without reverting back to Static TEACH.

Setting Sensitivity

Sensitivity is automatically set and optimized when the sensor is taught dynamically. When the push button is depressed and held, the sensor continues to sample events and registers them into memory. Upon release of the button, the sensor chooses the optimum setting for the application and then returns to RUN mode.

Dynamic Sampling Rate

When using Dynamic TEACH to sample an application for programming, it is important to consider the speed of the object being sensed. The sensor's sampling rate during this set-up process is much slower than its response time in RUN mode. Once sampling is complete and the sensor returns to RUN mode, sensor response time returns to its original value.

Use the following formula to calculate the target object speed for Dynamic TEACH sampling:

$$\text{Max. speed of object as it passes the sensor} = \frac{\text{Width of object (in inches) — effective beam (0.07")}}{\text{Dynamic Sampling Rate (0.009 seconds)*}}$$

For example, for an object 0.125" wide:

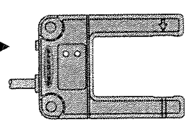
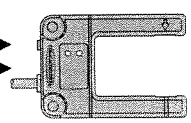
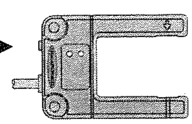
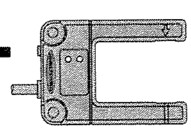
$$\text{Max. object speed} = \frac{(0.125" - 0.07")}{0.009 \text{ seconds}} = \mathbf{6.1"/second}$$

Or for an object 2 mm wide:

$$\text{Max. object speed} = \frac{(2 - 1.8 \text{ mm})}{0.009 \text{ seconds}} = \mathbf{22.2 \text{ mm/second}}$$

* NOTE: The Dynamic Sampling Rate for high-speed models ("Y" model suffix) is 8 milliseconds (0.008 seconds)

Dynamic TEACH Sequence

Push Button		Resulting Indicator Status
Press and hold until the bi-color (green/red) indicator begins to flash red, or turns OFF.	**Push and Hold** ➡ **≥ 2 Seconds** 	**Yellow:** ON **Red:** Pulses to indicate relative received signal strength.
Initiates Dynamic TEACH Mode	**Double-Click** ⇄ 	**Yellow:** Pulses at 0.5 Hz. **Red:** ON
Starts TEACH Process Present the sensing condition while holding the button	**Push and Hold** ➡  **Sensing Condition**	**Yellow:** ON Solid **Red:** ON Solid
Ends TEACH Process	**Release** ⬅ 	If contrast is acceptable, the sensor returns to RUN mode. Otherwise, it will return to Static TEACH mode; double-click to initiate Dynamic TEACH. **Green:** ON (or flashes if signal is close to the switching threshold). **Yellow:** ON or OFF, depending on condition

†NOTE: The sensor will return to RUN mode if the first TEACH condition is not registered within 90 seconds. Dynamic TEACH mode may be cancelled by waiting 90 seconds or by cycling sensor power.

Remote Programming

The gray wire of the SLE30 *Expert* may be connected to a remote switch or process controller to disable or enable the push button (four-pulse) or to program the sensor (single-pulse) through TEACH mode. Remote programming may be done for both the Static and Dynamic TEACH procedures.

A remote programming switch is connected between the gray wire and dc common (see hookup diagrams on page 9). The switch may be either a normally-open contact, or an open-collector NPN transistor with its emitter connected to dc common.

Programming is accomplished using a specified sequence of input pulses. The duration of each pulse is defined as: 0.04 seconds < T < 0.8 seconds.

The required spacing between adjacent pulses in a sequence (a "four-pulse") is also: 0.04 < T < 0.8 seconds. The timing diagrams (Figure 3, right) illustrate the input requirements.

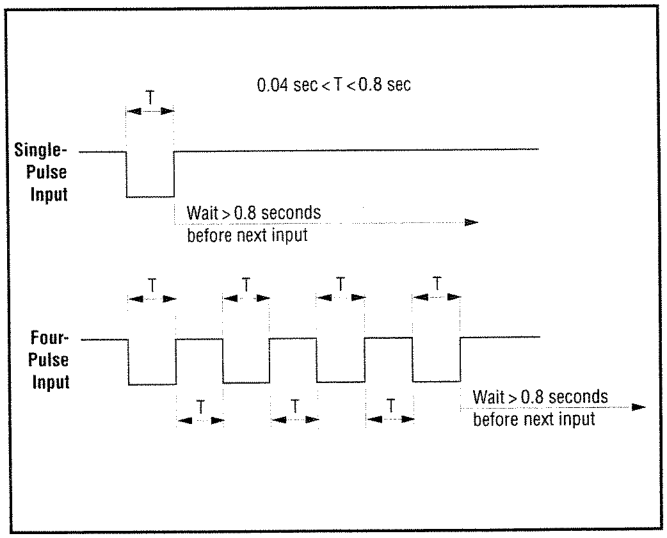


Figure 3. Timing programs for remote programming

Locking Out (Disabling) the Push Button

When remote programming is used exclusively, it may be beneficial to disable the push button on the SLE30 *Expert* to increase the security of the settings. The push button can be enabled and/or disabled via the remote line only. If the push button is disabled, TEACH mode cannot be accessed from the push button.

Pulse the Remote TEACH line 4 times (four-pulse) to enable or disable the push button (see timing diagram, Figure 3).

Static TEACH Programming Using the Remote TEACH Line

To pulse the TEACH line, momentarily connect the remote wire to dc common (no press-and-hold procedure is required to enter TEACH mode). This is the equivalent of a "click" when using the sensor TEACH push button.

1. Position the "Output ON" condition and pulse the Remote TEACH line once. The bi-color (green/red) indicator begins to flash red or turn OFF (the AID™ function is indicating signal strength) and the yellow Output indicator will flash briefly and then go OFF.

2. Position the "Output OFF" condition and pulse the Remote TEACH line again. The green indicator will turn ON and the sensor will return to RUN mode with the new settings, if the contrast is adequate. If the contrast is not adequate, the yellow indicator will turn ON and the red AID indicator will remain active, indicating that the sensor is waiting for the first TEACH condition to be retaught. (RUN mode begins a few seconds after the end of TEACH mode.

NOTE: To exit Static TEACH without updating, hold the Remote TEACH line low (longer than 2 seconds) until the green indicator goes ON, *before teaching the second target.*

Dynamic TEACH Programming Using the Remote TEACH Line

To pulse the TEACH line, momentarily connect the Remote (gray) wire to dc common; no press-and-hold procedure is required to enter TEACH mode. (This is the equivalent of a "click" when using the sensor TEACH push button.)

1. Using the Static TEACH procedure, set up the application's Output ON and OFF conditions. (This step is not necessary if the Output ON and OFF conditions already are configured properly for your application.)
2. Double-pulse the Remote TEACH line (see Figure 3). The sensor is now ready for Dynamic TEACH. The bi-color (green/red) indicator will be ON solid red and the yellow indicator will flash.
3. Hold the Remote line low. Sample sensing events while continuing to hold the Remote line low.
4. Release the Remote line when event sampling is complete. The green indicator will turn ON and the sensor will return to RUN mode with the new settings, if the contrast is adequate.

If the contrast is not adequate, the red indicator will flash at a rate proportional to the received light signal strength and the yellow indicator will be ON solid, indicating that the sensor needs to be retaught. In this case, return to step 2.

NOTE: To exit Dynamic TEACH without updating, wait 90 seconds or cycle sensor power.

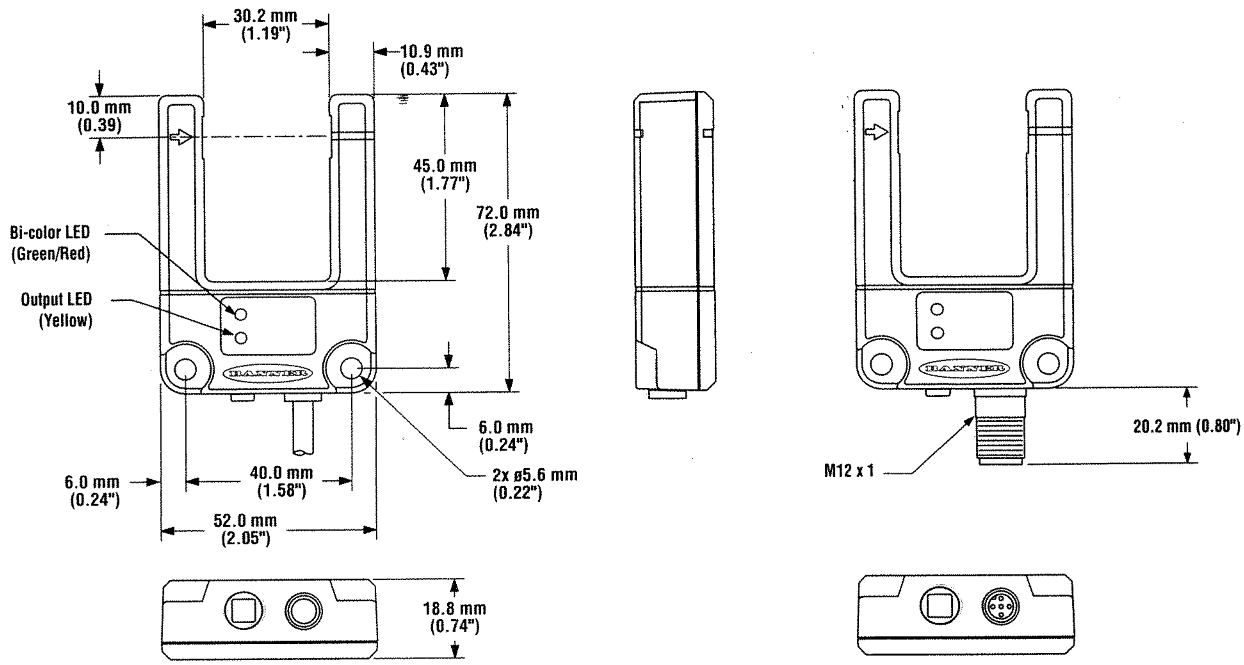
Troubleshooting

The SLE30 *Expert's* Power LED may begin to alternate flashing red/green; this indicates a microprocessor memory error. If it occurs, try reteaching the sensor, or try cycling power ON and OFF, then reteaching the sensor. If this does not solve the problem, or if it occurs frequently, replace the sensor.

SLE30 *Expert* Series Slot Sensor Specifications

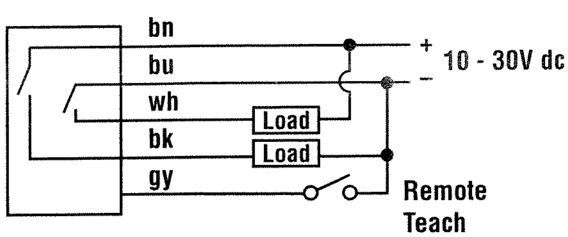
Supply Voltage and Current	10 to 30V dc (10% maximum ripple) at less than 45 mA, exclusive of load
Supply Protection Circuitry	Protected against reverse polarity and transient voltages
Output Configuration	Bipolar: One current sourcing (PNP) and one current sinking (NPN) open-collector transistor
Output Rating	150mA maximum each output at 25°C, derated to 100 mA at 70°C (derate ≈1 mA per °C) **OFF-state leakage current:** less than 5µA @ 30V dc **ON-state saturation current:** less than 1V @ 10 mA; less than 1.5V @ 150 mA
Output Protection Circuitry	Protected against false pulse on power-up and continuous overload or short-circuit of outputs
Output Response Time	Sensors will respond to either a "light" or a "dark" signal of 500 microseconds (or 150 microseconds, depending on model) or longer duration, 1 kHz max. NOTE: 1 second delay on power-up; outputs are non-conducting during this time.
Repeatability	100 microseconds or 75 microseconds, depending on model
Effective Beam	1.8 mm (0.07")
Adjustments	Push-button TEACH mode sensitivity setting (see TEACH mode, page 3); remote TEACH mode input is provided (gray wire)
Indicators	Two LEDs: Yellow and Bi-color Green/Red **Green (RUN Mode):** ON when power is applied Flashes when received light level approaches the switching threshold **Red (TEACH Mode):** OFF when no signal is received. Pulses to indicate signal strength (received light level). Rate is proportional to signal strength (the stronger the signal, the faster the pulse rate). This is a function of Banner's patented Alignment Indicating Device (AID™, US patent 4356393). **Alternating Red/Green: Flashing** Microprocessor memory error (see Troubleshooting, page 7) **Yellow (Static TEACH):** ON to indicate sensor is ready to learn output ON condition OFF to indicate sensor is ready to learn output OFF condition **Yellow (Dynamic TEACH):** Pulses at 0.5 Hz when ready to sample ON to indicate Dynamic TEACH sampling OFF to indicate sampling was accepted **Yellow (RUN Mode):** ON when outputs are conducting
Construction	ABS/polycarbonate housing, acrylic lenses
Environmental Rating	Meets NEMA 6; IEC IP67
Connections	PVC-jacketed 5-conductor 2 m (6.5') or 9 m (30') unterminated cable, or 5-pin Euro-style quick-disconnect (QD) fitting are available. QD cables are ordered separately; see page 10.
Operating Conditions	**Temperature:** -20° to +70°C (-4° to +158°F) **Maximum relative humidity:** 90% at 50°C (non-condensing)
Application Notes	The first condition presented during TEACH mode becomes the output ON condition.

SLE30 *Expert* Series Slot Sensor Dimensions

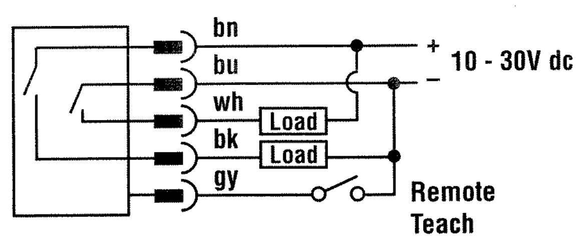


SLE30 *Expert* Series Slot Sensor Hookups

Cabled Models



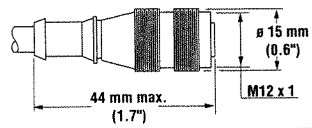
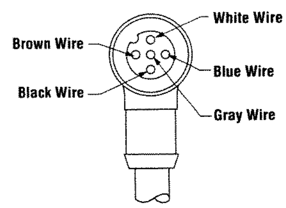
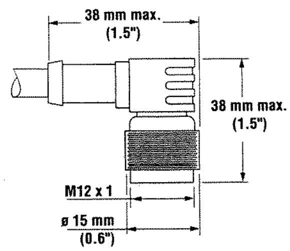
Quick-Disconnect Models



Accessories

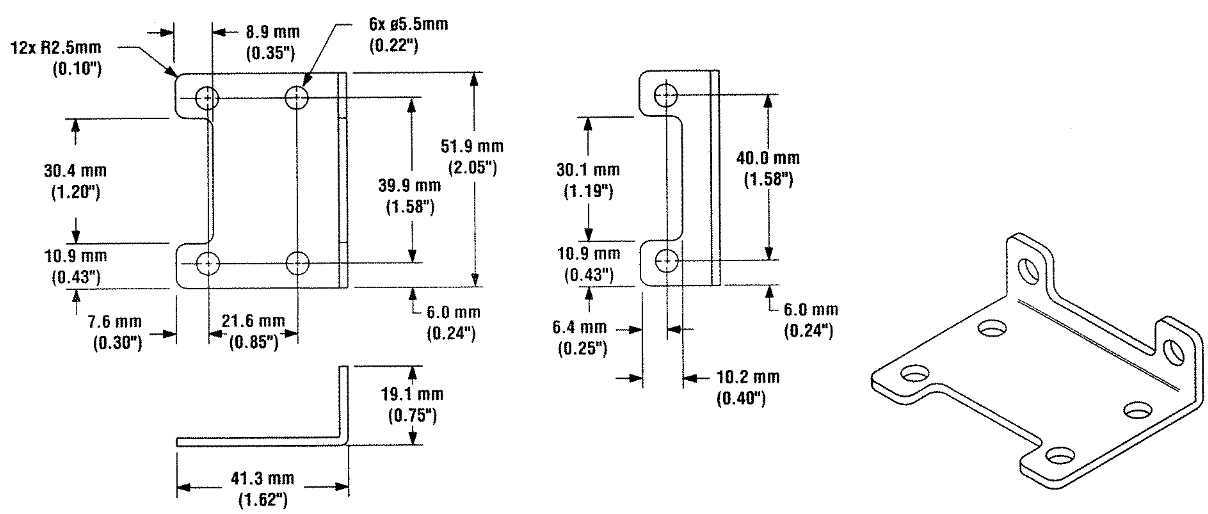
Quick-Disconnect Cables

The following cables are available for SLE30 *Expert* Series Slot Sensor QD models

Style	Model	Length	Dimensions	Pin-out
5-pin Euro-style straight	**MQDC1-506** **MQDC1-515** **MQDC1-530**	2 m (6.5') 5 m (15') 9 m (30')		
5-pin Euro-style right-angle	**MQDC1-506RA** **MQDC1-515RA** **MQDC1-530RA**	2 m (6.5') 5 m (15') 9 m (30')		

Mounting Brackets

SMBSL	• Angled bracket • 304 stainless steel; hardware included



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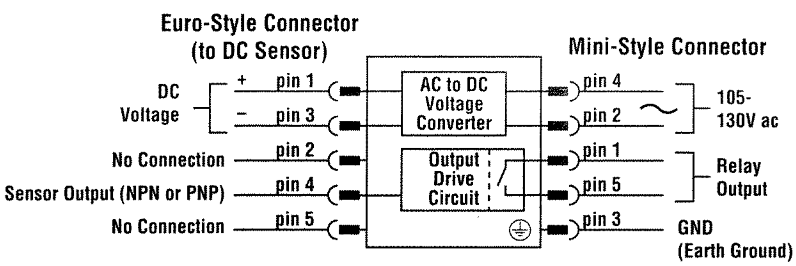
WARRANTY: Banner Engineering Corp. warrants its products to be free from defects for one year. Banner Engineering Corp. will repair or replace, free of charge, any product of its manufacture found to be defective at the time it is returned to the factory during the warranty period. This warranty does not cover damage or liability for the improper application of Banner products. This warranty is in lieu of any other warranty either expressed or implied.

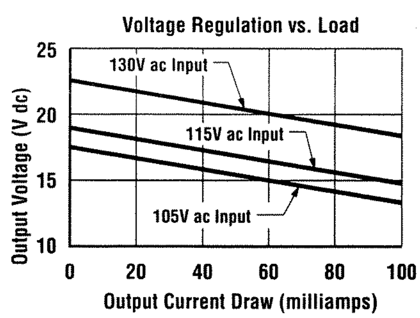
SPS101 DC Sensor Power Supply

SPS101 Sensor Power Supply Specifications

Supply Voltage	105V ac to 130V ac, 60Hz
Output Power	120mA maximum: 12V dc minimum, 30V dc maximum (dependent on load)
Output Configuration	**SPS101Q(P) models:** "Form A" (SPST) electromechanical relay **SPS101SQ(P) models:** Optically isolated SPST solid-state switch
Output Rating NOTE: Output of the solid-state models is not short-circuit protected. Exercise care when making wiring connections.	**SPS101Q(P) models** **Max. switching power (resistive load):** 150 W, 600 VA **Max. switching voltage (resistive load):** 250V ac or 30V dc (120V ac max. per UL & CSA) **Max. switching current (resistive load):** 5A **Min. voltage and current:** 1 amp at 5V dc, 0.1 amp at 24V dc **Peak switching voltage:** 750V ac (transient suppression recommended) **Mechanical life of relay:** 10,000,000 operations **SPS101SQ(P) models** **Max. switching voltage:** 250V ac or 250V dc **Max. switching current:** 300 mA **On-state saturation voltage:** less than 3V at 300 mA; less than 2V at 15 mA **Off-state leakage current:** < 50 microamps **Inrush current:** 1 amp for 20 milliseconds, non-repetitive
Status Indicators	Power On (green) and Output On (red)
Connections	**Power connector:** 5-pin Mini-style quick disconnect **Sensor connector:** **"Q" version:** 5-pin Euro-style quick-disconnect mounted on housing **"QP" version:** Shielded, PVC jacketed 5-pin pigtail Euro-style quick-disconnect, 0.5 meter long
Environmental Rating	IEC IP54
Operating Conditions	**Temperature:** -20° to +50°C (-4° to 122°F) **Maximum Relative Humidity:** 90% @ +50°C (non-condensing)
Additional Notes	Compatible with Banner dc sensors with NPN or PNP output, equipped with 4- or 5-pin Euro-style quick-disconnect (except NAMUR sensors). Minimum of 630V isolation from earth ground to dc output of circuit.

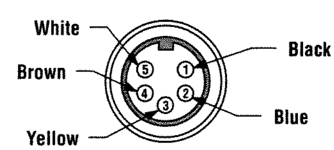
SPS101 Sensor Power Supply Hookups





WARRANTY: Banner Engineering Corp. warrants its products to be free from defects for one year. Banner Engineering Corp. will repair or replace, free of charge, any product of its manufacture found to be defective at the time it is returned to the factory during the warranty period. This warranty does not cover damage or liability for the improper application of Banner products. This warranty is in lieu of any other warranty either expressed or implied.

Quick-Disconnect Cables

Style	Model	Length	Pin-Out (Female View)
5-Pin Mini-Style Straight	**MBCC-506** **MBCC-512** **MBCC-530**	2 m (6.5') 4 m (12') 9 m (30')	

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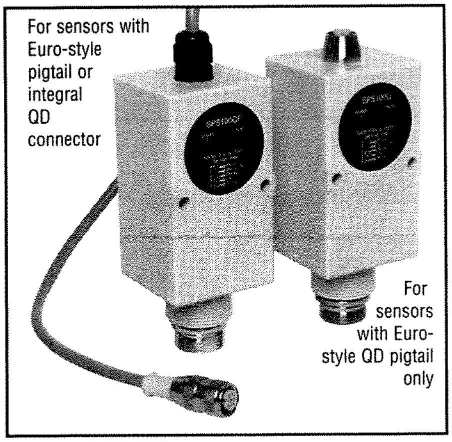
SPS101 DC Sensor Power Supply

For Powering Banner dc Sensors



SPS101 Features

- Converts 120V ac line voltage to low voltage dc for powering any Banner dc sensor† which has either 4- or 5-pin Euro-style quick-disconnect (QD)
- **SPS101 models:** 5 amp-rated SPST relay for switching ac loads or large dc loads
- **SPS101S models:** optically-isolated SPST solid-state output for switching ac or dc loads
- Models with "Q" suffix require a sensor with a pigtail QD connector; models with "QP" suffix connect to a sensor with either an integral or pigtail quick-disconnect
- Isolated dc output

† Note: SPS power supplies are not for use with NAMUR sensors or personal safety products.

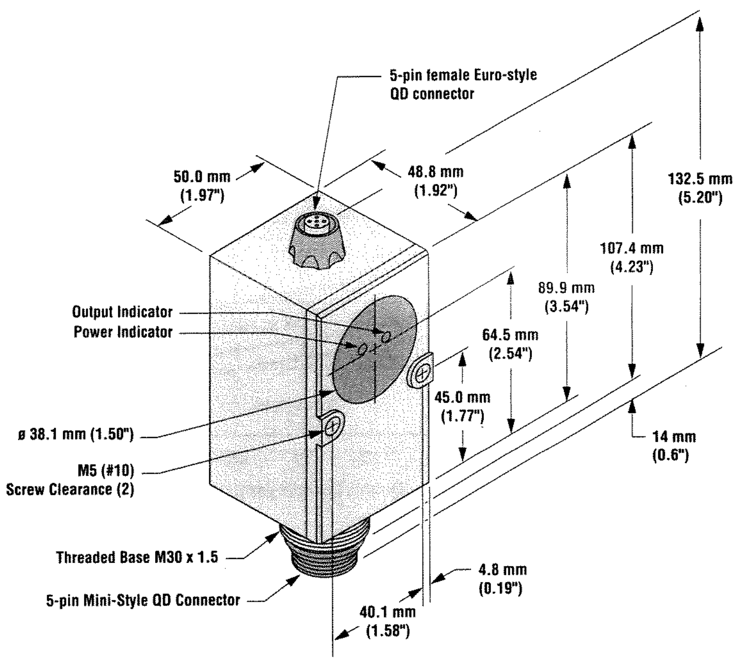
SPS101 Sensor Power Supply Models

Model	Supply Voltage	Sensor Connection	Supply/Output Cable	Output Type
SPS101Q	105-130V ac 60 Hz	5-pin Euro-style QD*	5-pin Mini QD	"Form A" (SPST) electromechanical relay (see specifications for rating information)
SPS101QP		5-pin Pigtail Euro-style QD		
SPS101SQ		5-pin Euro-style QD*		SPST Optically-isolated solid-state switch (see specifications for rating information)
SPS101SQP		5-pin Pigtail Euro-style QD		

*Requires 4- or 5-pin Pigtail Euro QD on sensor.

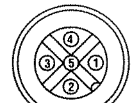
SPS101 Sensor Power Supply Dimensions

Model Suffix "Q"

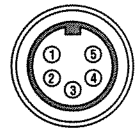


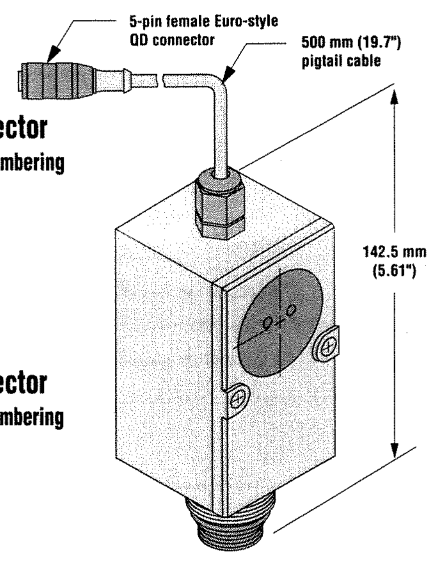
Model Suffix "QP"

Euro-Style Connector
"QD" Receptacle Pin Numbering (Female Pins)



Mini-Style Connector
"QD" Receptacle Pin Numbering (Male Pins)





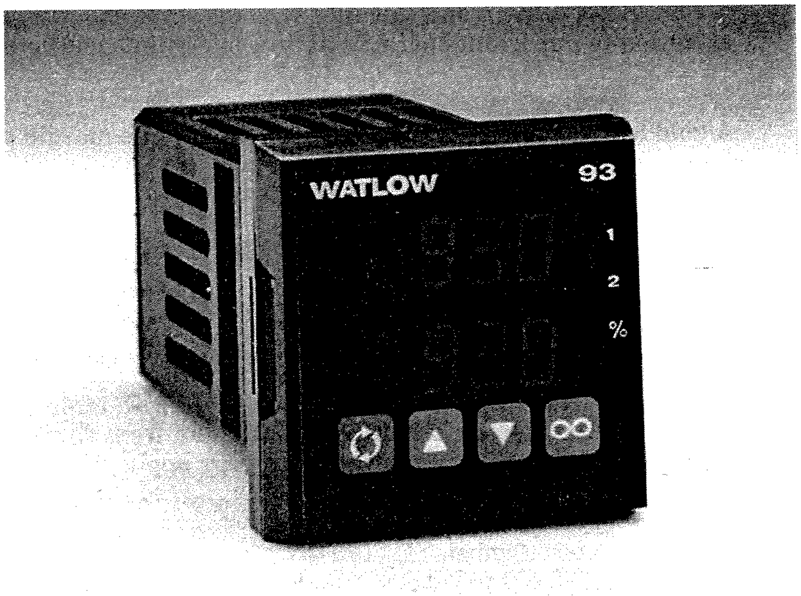
WARNING . . . Not To Be Used for Personnel Protection

Never use these products as sensing devices for personnel protection. Doing so could lead to serious injury or death.

These sensors do NOT include the self-checking redundant circuitry necessary to allow their use in personnel safety applications. A sensor failure or malfunction can cause either an energized or de-energized sensor output condition. Consult your current Banner Safety Products catalog for safety products which meet OSHA, ANSI and IEC standards for personnel protection.

Series 93

User's Manual



1/16 DIN Microprocessor-Based Auto-tuning Control

CE

TOTAL
CUSTOMER
SATISFACTION
3 Year Warranty

ISO 9001
Registered Company
Winona, Minnesota USA

WATLOW

1241 Bundy Blvd., P.O. Box 5580, Winona, Minnesota USA 55987-5580
Phone: (507) 454-5300, Fax: (507) 452-4507 http://www.watlow.com

0600-0001-0000 Rev D
April 2002
Supersedes 0600-0001-0000 Rev C

Made in the U.S.A.
$10.00

NOTE:
Details of a "Note" appear here in the narrow margin on the left side of each page.

⚠ **CAUTION:**
Details of a "Caution" appear here in the narrow margin on the left side of each page.

⚠ **WARNING:**
Details of a "Warning" appear here in the narrow margin on the left side of each page.

Safety Information

We use note, caution and warning symbols throughout this book to draw your attention to important operational and safety information.

A bold text "NOTE" marks a short message in the margin to alert you to an important detail.

A bold text "CAUTION" safety alert appears with information that is important for protecting your equipment and performance. Be especially careful to read and follow all cautions that apply to your application.

A bold text "WARNING" safety alert appears with information that is important for protecting you, others and equipment from damage. Pay very close attention to all warnings that apply to your application.

The safety alert symbol, ⚠, (an exclamation point in a triangle) precedes a general CAUTION or WARNING statement.

The electrical hazard symbol, ⚠, (a lightning bolt in a triangle) precedes an electric shock hazard CAUTION or WARNING safety statement.

Technical Assistance

If you encounter a problem with your Watlow controller, review all of your configuration information for each step of the setup, to verify that your selections are consistent with your applications. If the problem persists after checking the above, you can get technical assistance from your local Watlow representative, or by dialing (507) 454-5300.

An applications engineer will discuss your application with you.

Please have the following information available when calling:

- Complete model number
- User's Manual
- All configuration information

Your Feedback

Your comments or suggestions on this manual are welcome, please send them to: Technical Writer, Watlow Winona, 1241 Bundy Blvd., P.O. Box 5580, Winona, MN 55987-5580, Phone: (507) 454-5300, Fax: (507) 452-4507.

TC Table of Contents

Figures and Tables

Notes

1 Overview of the Series 93

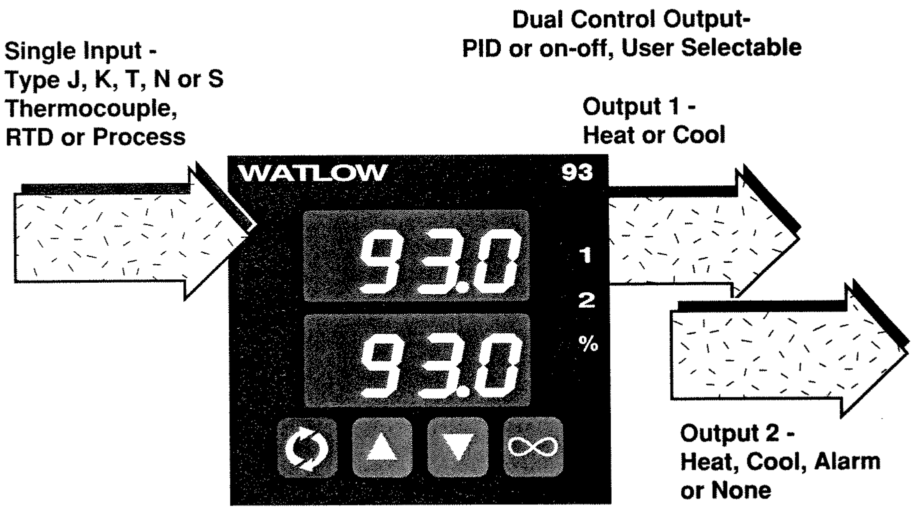


Figure 1.1 - Series 93 Input and Output Overview.

General Description

Welcome to the Watlow Series 93, a 1/16 DIN microprocessor-based temperature controller. The 93 has a single input which accepts type J, K, T, N or S thermocouple, RTD or process input.

With dual output, the primary output can be heating or cooling while the secondary output can be a control output opposite the primary output (heat or cool), alarm or none. Both outputs can be selected as either PID or on-off. PID settings include proportional band, reset/integral, and rate/derivative. Setting the proportional band to zero makes the Series 93 a simple on-off controller with switching differential selectable under the [HSC] parameter.

Special 93 features include the optional NEMA 4X rating, optional CE compliance, dual four-digit displays in either red or green, optional low-voltage power supply, autotuning for both heat and cool outputs, ramp to set point for gradual warm-up of your thermal system, and automatic/manual capability with bumpless transfer.

Operator-friendly features include automatic LED indicators to aid in monitoring and setup, as well as a calibration offset at the front panel. The Watlow Series 93 automatically stores all information in a non-volatile memory.

Notes

Overview

2 Install and Wire the Series 93

NOTE:

For rapid mounting, use Greenlee 1/16 DIN punch, die, draw stud, part number 60287.

NOTE:

Measurements between panel cutouts are the minimum recommended.

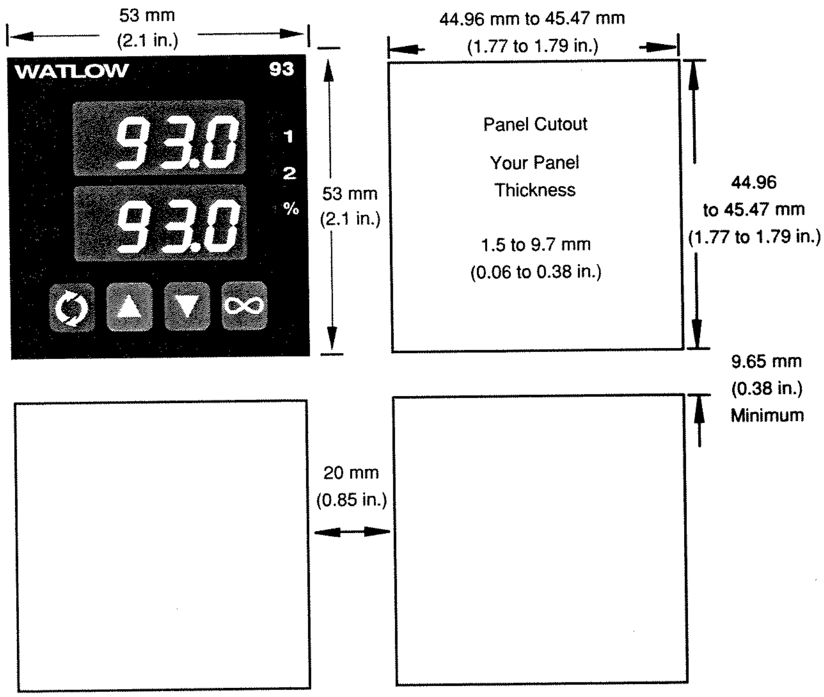


Figure 2.1a - Series 93 Multiple Panel Cutout Dimensions.

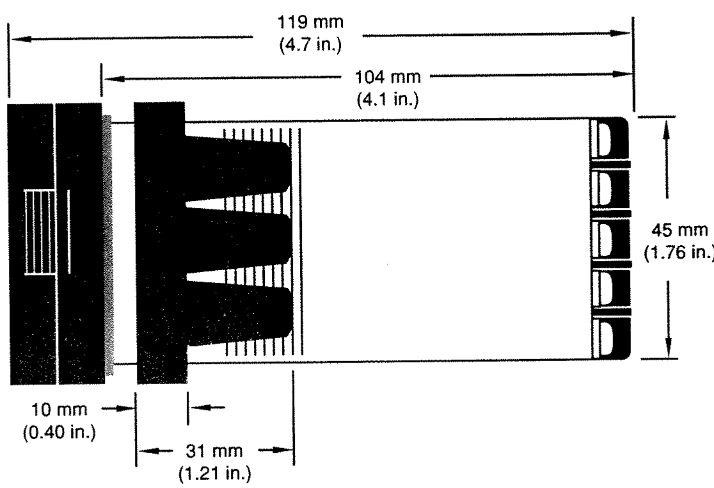


Figure 2.1b- Series 93 Dimensions.

Installation procedure

Bold print denotes requirement for IP65 (NEMA 4X) seal. Follow this procedure to mount the Watlow Series 93 temperature controller:

1. Make a panel cutout using the dimensions in Figure 2.1a.
2. **If your controller model number begins with 93B, make sure the rounded side of the external case gasket is facing the panel surface.** Check to see that the gasket is not twisted, and is seated within the case bezel flush with the panel. Place the case in the cutout. Make sure the gasket is between the panel cutout and the case bezel.

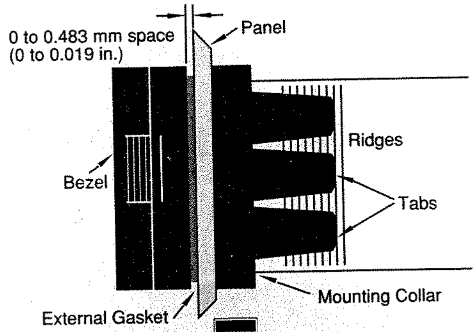


Figure 2.2a -
Mounting Case Side View.

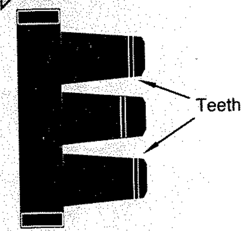


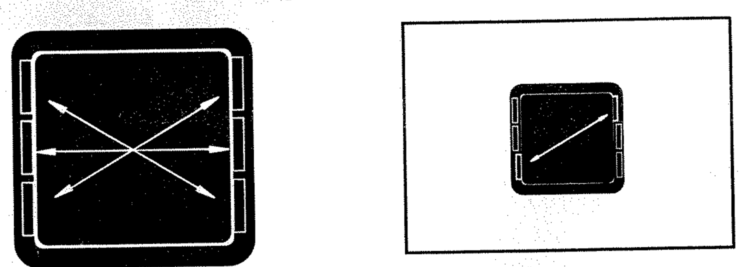
Figure 2.2b -
Mounting Collar Cross Section with offset teeth.

3. While pressing the front of the case firmly against the panel, slide the mounting collar over the back of the controller. The tabs on the collar must line up with the mounting ridges on the case for secure installation. See Figure 2.2a. Slide the collar firmly against the back of the panel getting it as tight as possible.

   To ensure a tight seal, use your thumb to lock the tabs into place while pressing the case from side to side. Don't be afraid to apply enough pressure to install the controller. The tabs on each side of the collar have teeth which latch into the ridges. See Figure 2.2b. Each tooth is staggered at a different height, so only one of the tabs on each side are ever locked into the ridges at any time.

   Confirm that the tabs on one side of the collar correspond with those on the opposite side. Make sure the two corresponding tabs are the only ones locked in the ridges at the same time.
   If the corresponding tabs are not supporting the case at the same time, and the space between the panel and the case bezel is greater than .019 inch, you will will not have a IP65 (NEMA 4X) seal. This applies to units with models designated 93B. However, all units should be mounted in this fashion to guarantee integrity of the mounting system.

CAUTION: Follow the installation procedure exactly to guarantee a proper IP65 (NEMA 4X) seal. Make sure the gasket between the panel and the rim of the case is not twisted and is seated properly. Failure to do so could result in damage to equipment.



Make sure that the two corresponding tabs are locked in the ridges at the same time.

IP65 (NEMA 4X) Seal Example.

Figure 2.2c -
Case Rear View and IP65 (NEMA 4X) Seal Example.

4. Insert the controller chassis into its case and press the bezel to seat it. Make sure the inside gasket is also seated properly and not twisted. The hardware installation is complete. Proceed to the wiring section from here.

Removing the Series 93 Controller

When removing the mounting collar, we suggest using a thin tool such as a putty knife or screwdriver to pry gently under each of the six tabs to disengage the teeth. Then rock the collar back and forth until it can be easily pulled off the case.

Wiring the Series 93

WARNING: To avoid electric shock, use National Electric Code (NEC) safety practices when wiring and connecting this unit to a power source and to electrical sensors or peripheral devices. Failure to do so could result in injury or death.

The Series 93 wiring is illustrated by model number option. Check the unit sticker on the controller and compare your model number to those shown here and also the model number breakdown in the Appendix of this manual.

All outputs are referenced to a de-energized state. The final wiring figure is a typical system example.

When you apply power without sensor inputs on the terminal strip, the Series 93 displays [- - - -] in the upper display, and [0] in the lower display, except for 0-5V⎓ (dc) or 4-20mA process input units. Press the ∞Infinity key twice, and [Er 7] is displayed for one second. This error indicates an open sensor or an analog-to-digital error. All wiring and fusing must conform to the National Electric Code and to any locally applicable codes as well.

NOTE:

Taking the unit out of the case is not a normal operating condition and should only be done by a qualified maintenance installation technician. Power to the case should be disconnected before removing or installing the controller into its case.

WARNING: The case terminals may still carry live voltage when the unit is removed.

WARNING: Irreversible damage will occur if high voltage is applied to the low voltage unit.

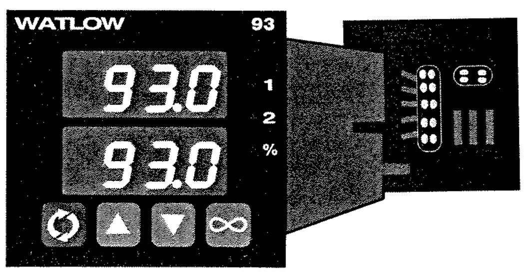
Power Wiring

High Voltage

100 to 240~ (ac), nominal (85 to 264 actual) 93_ _-1_ _ 0 - 00_ _

Low Voltage

12 to 24V≂ (ac/dc) 93_ _- 1_ _ 1 - 00_ _



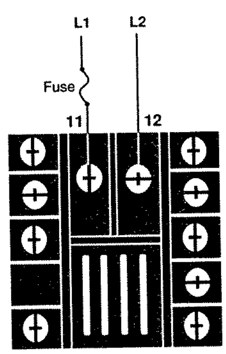
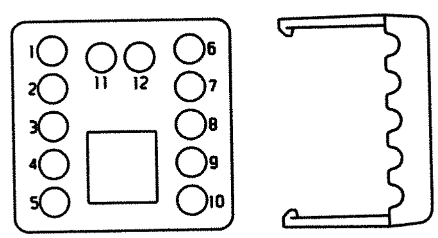


Figure 2.3 – Power Wiring.



NOTE: Optional protective rear terminal cover, 0822-0426-P001, is available. Contact Watlow customer service or your local Watlow sales representative.

WARNING: To avoid electric shock and damage to property and equipment, use National Electric Code (NEC) safety practices when wiring and connecting this unit to a power source and to electrical sensors or peripheral devices. Failure to do so could result in injury or death.

NOTE:

When an external device with a non-isolated circuit common is connected to the 4-20mA or dc output, you must use an isolated or ungrounded thermocouple.

Sensor Installation Guidelines

We suggest you mount the sensor at a location in your process or system where it reads an average temperature. Put the sensor as near as possible to the material or space you want to control. Air flow past this sensor should be moderate. The sensor should be thermally insulated from the sensor mounting.

See Chapter 4 for more information on DIP switch location and orientation.

Input Wiring

Figure 2.4a – **Thermocouple**

Extension wire for thermocouples must be of the same alloy as the thermocouple itself to limit errors.

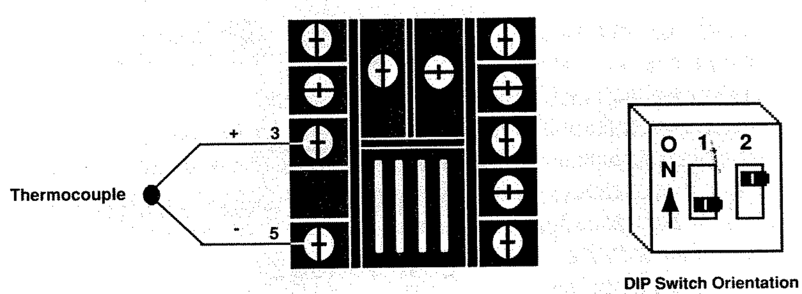
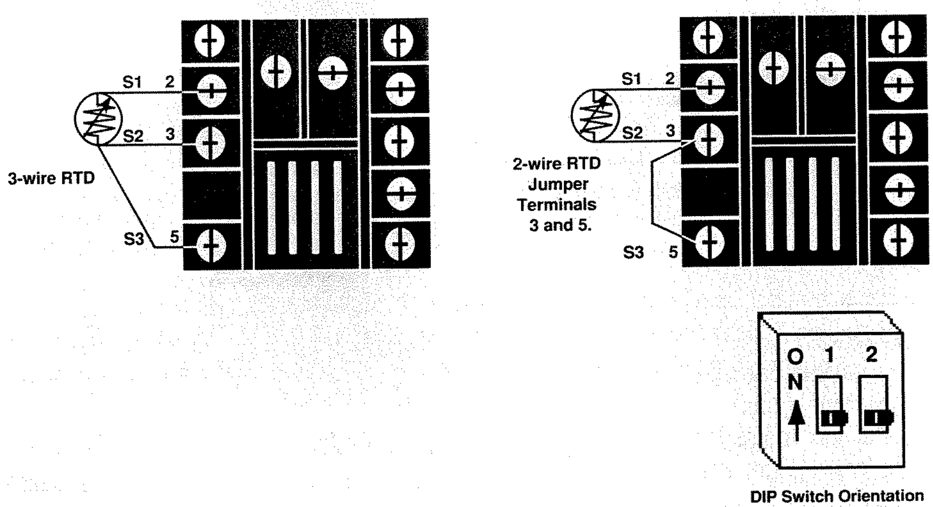


Figure 2.4b – **RTD (2- or 3-Wire) 100Ω Platinum**

There could be a + 2°F input error for every 1Ω of lead length resistance when using a 2-wire RTD. That resistance, when added to the RTD element resistance, will result in erroneous input to the instrument. To overcome this problem, use a 3-wire RTD sensor, which compensates for lead length resistance. When extension wire is used for a 3-wire RTD, all wires must have the same electrical resistance (i.e. same gauge, same length, multi-stranded or solid, same metal).



NOTE:

Successful installation requires four steps:

- Choose the controller's hardware configuration and model number (Appendix);
- Choose a sensor (Chapter Two and Appendix);
- Install and wire the controller (Chapter Two);
- Configure the controller (Chapters Three, Four and Five).

WARNING: To avoid damage to property and equipment, and/or injury or loss of life, use National Electric Code (NEC) standard wiring practices to install and operate the Series 93. Failure to do so could result in such damage, and/or injury or death.

NOTE:

When an external device with a non-isolated circuit common is connected to the 4-20mA or dc output, you must use an isolated or ungrounded thermocouple.

CAUTION: Process input does not have sensor break protection. Outputs can remain full on.

Figure 2.5a – 0-5V⎓ (dc) Process

Input impedance: 10kΩ

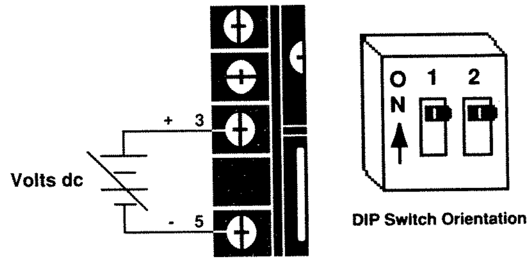


Figure 2.5b – 4-20mA Process

Input impedance: 5Ω

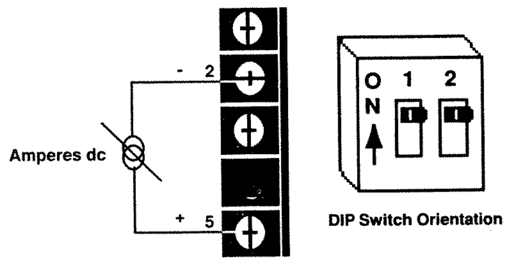
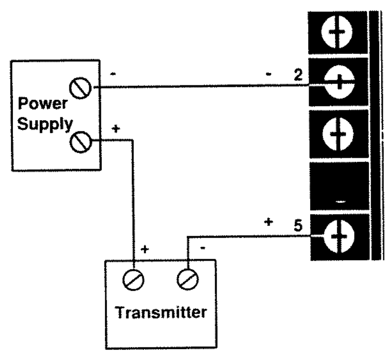


Figure 2.5c – 4-20mA Process: 2-Wire Transmitters



NOTE:

Successful installation requires four steps:

- **Choose the controller's hardware configuration and model number (Appendix);**
- **Choose a sensor (Chapter Two and Appendix);**
- **Install and wire the controller (Chapter Two);**
- **Configure the controller (Chapters Three, Four and Five).**

WARNING: To avoid damage to property and equipment, and/or injury or loss of life, use National Electric Code (NEC) standard wiring practices to install and operate the Series 93. Failure to do so could result in such damage, and/or injury or death.

NOTE:

Switching inductive loads (relay coils, solenoids, etc.) with the mechanical relay, switched dc or solid-state relay output options requires use of an R.C. suppressor.

Watlow carries the R.C. suppressor Quencharc brand name, which is a trademark of ITW Paktron. Watlow Part No. 0804-0147-0000.

Output 1 Wiring

Figure 2.6a – Mechanical Relay Without Contact Suppression

93_ _- 1 D _ _- 00 _ _

Form C, 5A

Minimum load current:
100mA @ 5V⎓ (dc)

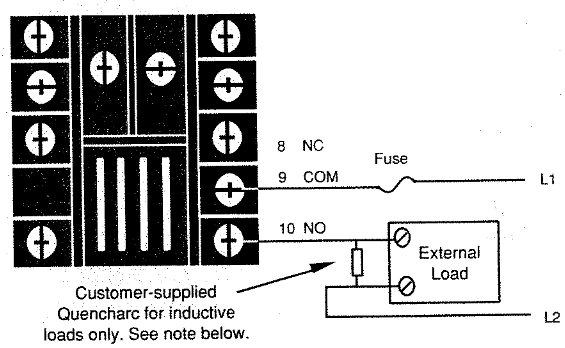
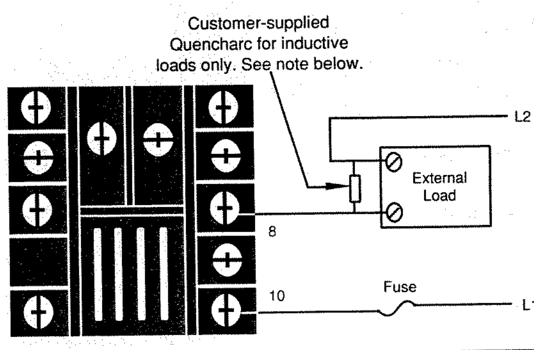


Figure 2.6b – Solid-state Relay Without Contact Suppression

93_ _- 1 K _ _- 00 _ _

0.5A (ac loads only)



NOTE:

Successful installation requires four steps:

- **Choose the controller's hardware configuration and model number (Appendix);**
- **Choose a sensor (Chapter Two and Appendix);**
- **Install and wire the controller (Chapter Two);**
- **Configure the controller (Chapters Three, Four and Five).**

NOTE:

When an external device with a non-isolated circuit common is connected to the 4-20mA or dc output, you must use an isolated or ungrounded thermocouple.

Figure 2.7a – **Switched DC**

93_ _- 1 C _ _- 00 _ _

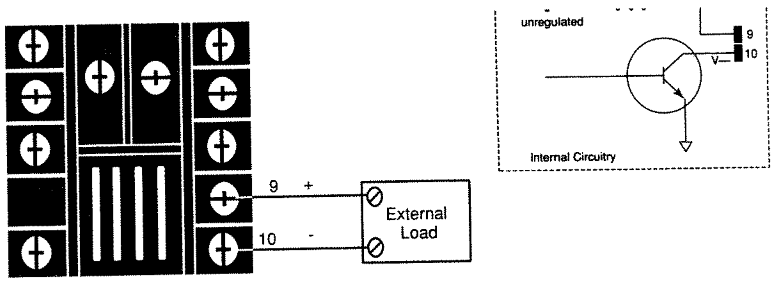
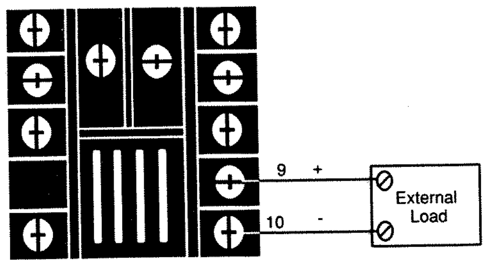


Figure 2.7b – **4-20mA Process**

93_ _- 1 F_ _- 00 _ _

Maximum load impedance: 800Ω



NOTE:

Successful installation requires four steps:

- Choose the controller's hardware configuration and model number (Appendix);
- Choose a sensor (Chapter Two and Appendix);
- Install and wire the controller (Chapter Two);
- Configure the controller (Chapters Three, Four and Five).

NOTE:

Output is in open state in Alarm Condition.

NOTE:

Switching inductive loads (relay coils, solenoids, etc.) with the mechanical relay, switched dc or solid-state relay output options requires use of an R.C. suppressor.

Watlow carries the R.C. suppressor Quencharc brand name, which is a trademark of ITW Paktron. Watlow Part No. 0804-0147-0000.

WARNING: To avoid damage to property and equipment, and/or injury or loss of life, use National Electric Code (NEC) standard wiring practices to install and operate the Series 93. Failure to do so could result in such damage, and/or injury or death.

Output 2 Wiring

Figure 2.8a – Mechanical Relay Without Contact Suppression

93_ _- 1 _ D _ - 00_ _

Form C, 5A

Minimum load current:

100mA @ 5V⎓ (dc)

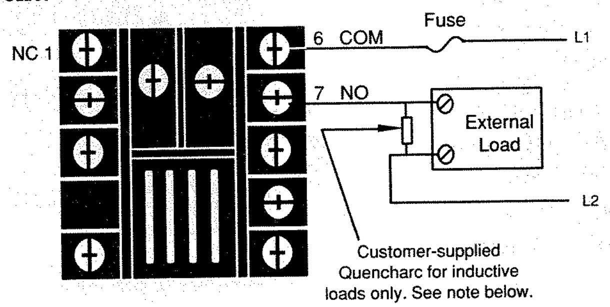


Figure 2.8b – Solid-state Relay Without Contact Suppression

93_ _- 1_ K _- 00_ _

0.5A (ac loads only)

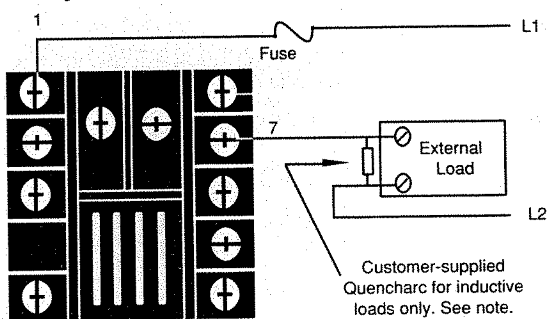
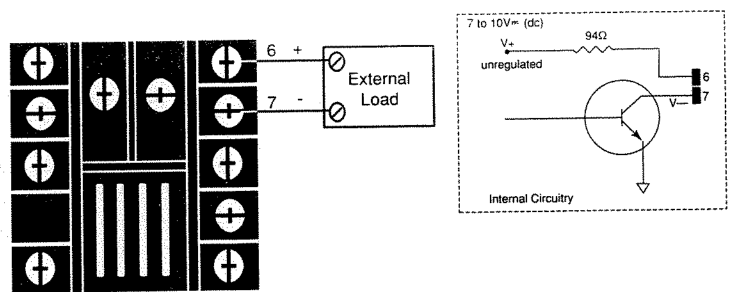


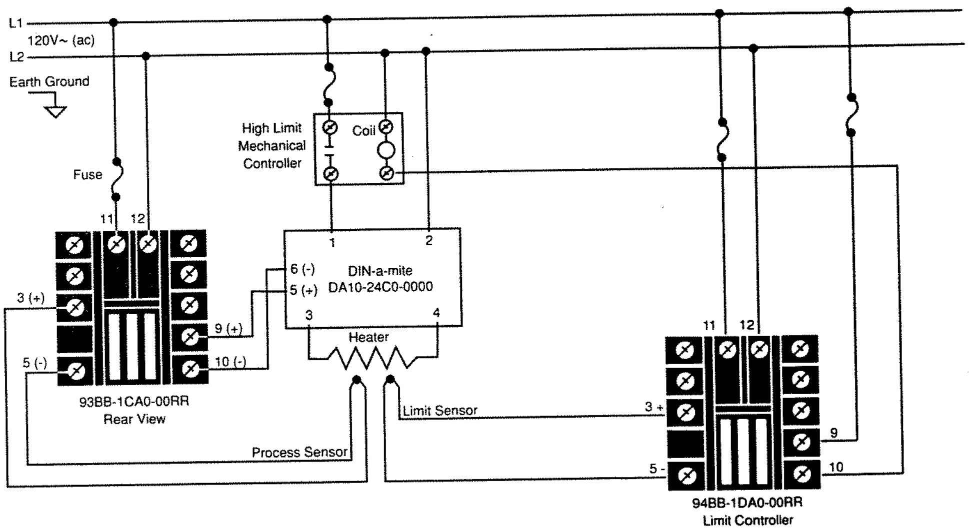
Figure 2.8c – Switched DC

93_ _- 1_ C _ - 00_ _



Wiring Example

WARNING: To avoid damage to property and equipment, and/or injury or loss of life, use National Electric Code (NEC) standard wiring practices to install and operate the Series 93. Failure to do so could result in such damage, and/or injury or death.



93BB-1CA0-00RR

1 Not used
2 S1, I-
3 S2, TC+, V+
4 Not used
5 S3, TC-, V-, I+
6 not used
7 not used
8 not used
9 D.C.+
10 D.C.-
11 L1
12 L2

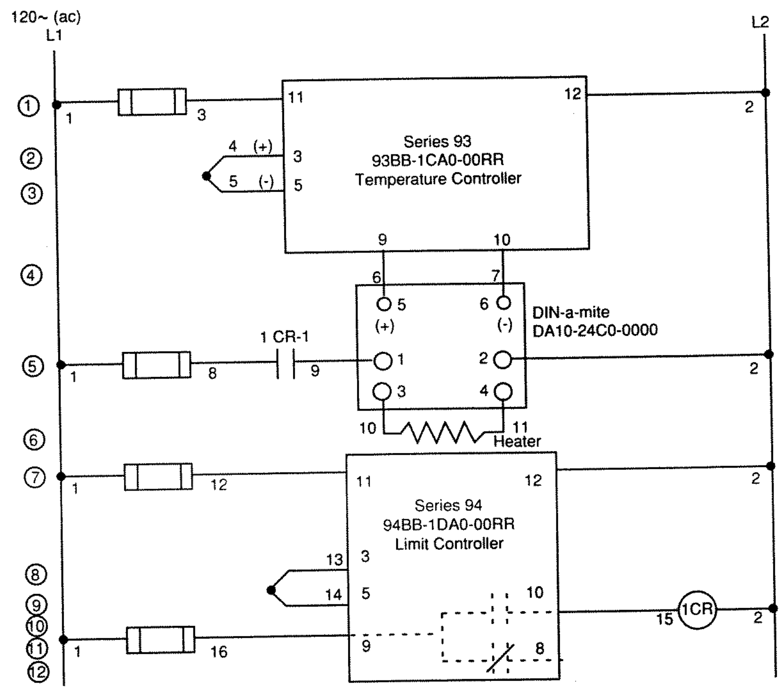


Figure 2.9 - System Wiring Example.

WARNING: To avoid electric shock and damage to property and equipment, use National Electric Code (NEC) safety practices when wiring and connecting this unit to a power source and to electrical sensors or peripheral devices. Failure to do so could result in injury or death.

WARNING: Install high or low temperature limit control protection in systems where an over temperature fault condition could present a fire hazard or other hazard. Failure to install temperature limit control protection where a potential hazard exists could result in damage to equipment, property and injury to personnel.

WARNING: All wiring and fusing must conform to the National Electric Code NFPA70. Contact your local board for additional information. Failure to observe NEC safety guidelines could result in injury to personnel or damage to property.

Wiring Notes

Sketch in your application on this page or a copy of it. See the wiring example in this chapter.

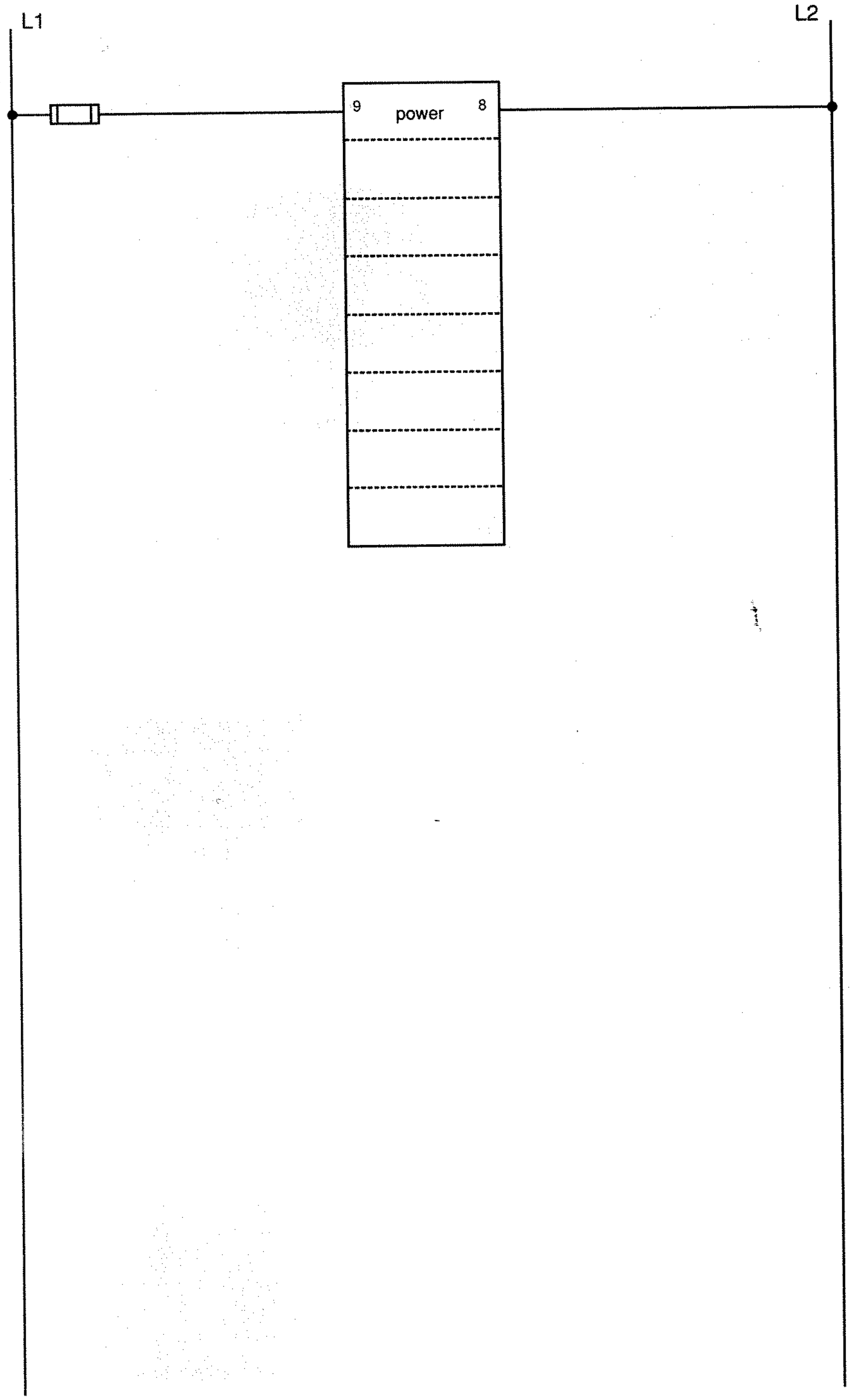


Figure 2.10 - Wiring Notes.

3 How to Use the Key and Displays

After 60 seconds with no key presses, the controller reverts to the default display — the process value in the upper display and the set point in the lower display.

Upper Display: Indicates the process value, actual temperature, operating parameter values or an open sensor. When powering up, the Process display will be blank for five seconds.
• To set to blank: set dSP to SEt in the Setup Menu.

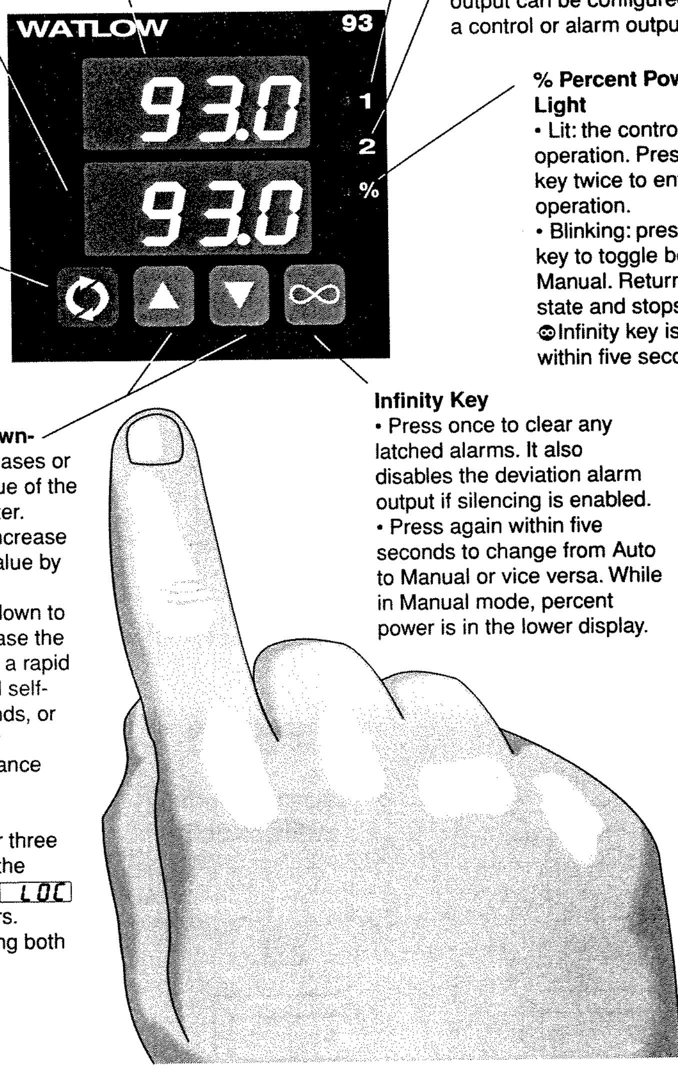
Output 1 Indicator Light: Lit when Output 1 is energized.

Lower Display: Indicates the set point, output value, parameters for data in the upper display, or error and alarm codes.
• To set to blank: set dSP to Pro in the Setup Menu.

Output 2 Indicator Light: Lit when Output 2 is active. This output can be configured as a control or alarm output.

% Percent Power Indicator Light
• Lit: the controller is in Manual operation. Press the ∞ Infinity key twice to enter Automatic operation.
• Blinking: press the ∞ Infinity key to toggle between Auto and Manual. Returns to its previous state and stops blinking if the ∞ Infinity key is not pressed within five seconds.

Advance Key: Press to step through the Operations, Setup and Calibration Menus.
In the Auto mode, new data is self-entering in five seconds.



Infinity Key
• Press once to clear any latched alarms. It also disables the deviation alarm output if silencing is enabled.
• Press again within five seconds to change from Auto to Manual or vice versa. While in Manual mode, percent power is in the lower display.

Up-arrow and Down-arrow Keys: Increases or decreases the value of the displayed parameter.
• Press lightly to increase or decrease the value by one.
• Press and hold down to increase or decrease the displayed value at a rapid rate. New data will self-enter in five seconds, or can be entered by pressing the Advance Key.
• Press both simultaneously for three seconds to enter the Setup Menu. The LOC parameter appears.
• Continue pressing both keys to enter the Calibration Menu.

Figure 3.1 - Series 93 Keys and Displays.

Notes

4 How to Set Up the Series 93

Setting up the Series 93 is a simple process. First set the DIP switches to match your input type. Refer to the orientation below for the [In] Input value. Next, configure the Series 93's features to your application in the Setup Menu, then enter values in the Operation Menu. Both tasks use the ⊛Advance key to move through the menus and the Up-arrow/Down-arrow keys to select data.

Before entering information in the Setup Menu, set the [dFL] parameter. If [SI] is selected, °C, proportional band in % of span, derivative and integral are the defaults. If [US] is selected, °F, proportional band in degrees, reset and rate are the defaults. **Changing the [dFL] prompt will set parameters to their factory default. Document all current parameter settings first.** See the calibration section in the Appendix to change this parameter.

Setting the Input Type DIP Switch

WARNING:

Remove power from the controller before removing the chassis from the case or changing the DIP switches. Removing the controller from the chassis is not a normal operating condition and should only be done by a qualified technician.

The Series 93 input type can be user selectable at any time via a Dual In-line Package (DIP) switch inside the control, located on the left (viewed from the bottom). To set the DIP switch, remove the control chassis from the case. Holding each side of the bezel, press in firmly on the side grips until the tabs release. You may need to rock the bezel back and forth several times to release the chassis.

The locations of the board and switches appear in Figure 4.1. Refer to the input types below for DIP switch orientation. The DIP switch configuration must match the sensor selected under the [In] parameter in the Setup Menu.

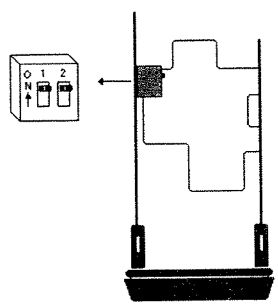


Figure 4.1a - DIP Switch Location and Orientation.

Controller Chassis - Bottom View

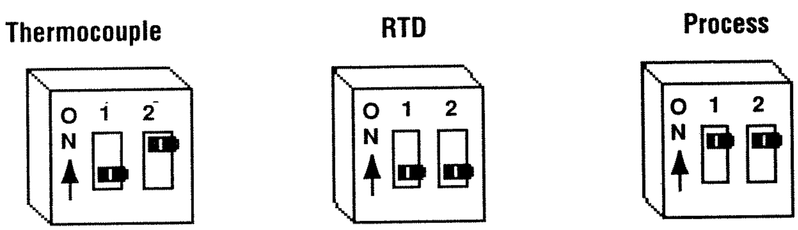


Figure 4.1b - Input DIP Switches.

Input Types

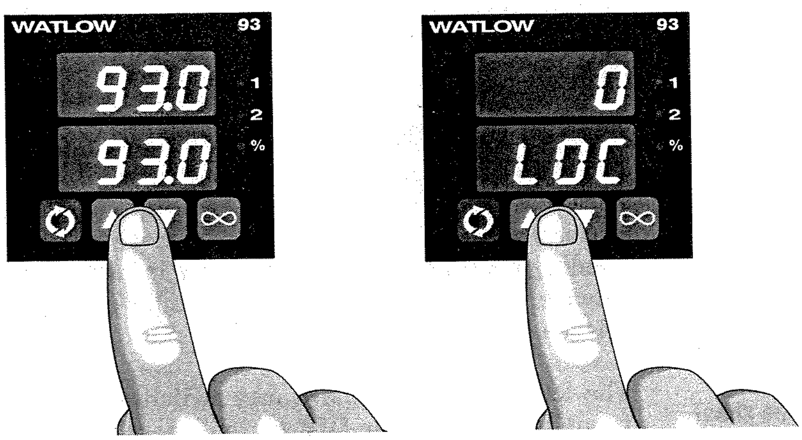
Menu Structure and Programming

The Series 93 controller has two menus that are used to determine the configuration and operation of the controller. They are the Setup Menu and the Operation Menu. If you are installing the Series 93 controller, you will need to determine the proper settings for both the Setup and Operation Menus. If the controller is already installed in equipment you have purchased, you may only need to set a few of the parameters to adjust the controller to your specific usage of the equipment. The Setup Menu displays the parameters that configure the Series 93's features to your application.

Entering the Setup Menu

Enter the Setup Menu by pressing the Up-arrow and Down-arrow keys simultaneously for 3 seconds. The lower display shows the [LOC] Lock parameter, and the upper display shows its current level. All keys are inactive until you release both keys. You can reach the Lock parameter from anywhere.

Figure 4.2a - Entering the Setup Menu.



Use the Advance key to move through the menus and the Up-arrow and Down-arrow keys to select data. You will not see all parameters in this menu, depending on the controller's configuration and model number. After stepping through the menu it returns to the set point parameter. If no keys are pressed for approximately 60 seconds, the controller returns to the default display, Process over Set Point.

Figure 4.2b - The Setup Menu.

NOTE:

While in the Setup Menu, all outputs are off.

Setup Menu

[LOC] Lock
[In] Input
[dEC] Decimal*
[C_F] Celsius - Fahrenheit*
[rL] Range Low
[rH] Range High
[Ot 1] Output 1
[HSC] Hysteresis Control
[Ot2] Output 2
[HSA] Hysteresis Alarm*
[LAt] Latching*
[S IL] Silencing*
[rtd] RTD*
[rP] Ramping
[rt] Rate*
[P L] Power Limiting*
[dSP] Display

* Parameter may not always appear.

Setup

Setup Parameters

NOTE:

Shaded parameters may not appear, depending on the controller's configuration and model number.

At the top of the Setup Menu the Series 93 displays the user level of operation in the upper display and the [LOC] parameter in the lower display.

Press the ⦿Advance key and the value of the next parameter appears in the upper display, and the parameter appears in the lower display.

[LOC]

NOTE:

Set the [LOC] parameter value as the final step in programming the Series 93 controller to prevent locking yourself out of the Operation and Setup Menu during initial programming.

⚠ **CAUTION:**

A process input does not have sensor break protection or bumpless transfer.

Lock: Selects the level of operator lock-out as defined below.
Range: 0 to 4 **Default:** 0

[0]: All operating parameters may be viewed or changed. Manual operation **is** permitted. When in manual operation, percent power is adjustable. Bumpless transfer to manual mode will occur on sensor break.

[1] The set point, process value and alarm settings are the only visible parameters, set point **is** adjustable in this level. Manual operation and autotune **are** permitted. When in manual operation, percent power is adjustable. Bumpless transfer to manual mode will occur on sensor break.

[2] The set point, process value and alarm settings are the only visible parameters, set point **is** adjustable in this level. Manual operation **is** permitted. When in manual operation, percent power is adjustable. Bumpless transfer to manual mode will occur on sensor break.

[3] The set point and process value are the only visible parameters, set point **is** adjustable in this level. Manual operation is **not** permitted. Bumpless transfer is defeated and outputs are disabled on sensor break.

[4] The set point and process value are the only visible parameters, set point is **not** adjustable in this level of lock-out. Manual operation is **not** permitted. Bumpless transfer is defeated and outputs are disabled on sensor break.

⚠ **CAUTION:**

Changing [In] sets all parameters to factory defaults. Document all settings before changing this parameter.

[In]

Input: Selects the sensor input type. The internal DIP switch must also match the [In] parameter. See DIP switch orientation, and see input type temperature ranges in the following chart. See ⚠ CAUTION at right.
Range: [J], [H] (K), [t], [n], [S], [rtd], [rt.d], [0-5], [420] **Default:** J

[dEC]

Decimal: Selects the location of the decimal point for all process-related data. This parameter only appears if the [In] parameter is set to 0-5 or 420. Make sure the internal DIP switch matches the [In] parameter.
Range: 0, 0.0, 0.00 **Default:** 0

[C-F]

Celsius — Fahrenheit: Selects the units of temperature measurement for the control. This parameter only appears if the [In] parameter is set to a thermocouple or RTD input. The default is dependent on the [dFL] parameter located in the Calibration Menu. Refer to the Appendix.
Range: [C] or [F]
If [dFL] is set to [SI]: **Default:** [C]
If [dFL] is set to [US]: **Default:** [F]

[rL]

Range Low: Selects the low limit of the set point. Also used to scale the low end of the process input. 0.0V⎓ (dc) and 4mA represent [rL] Range Low for a process input. The process input is linearly scaled between [rL] and [rH]. See the model number and specification in the Appendix for range values, or refer to the following table.
Range: Sensor range low to [rh] Range High
Default: Low limit of sensor type for a thermocouple or RTD. -500 for a process input.

Setup

rh

Range High: Selects the high limit of the operating range. Also used to scale the high end of the process input. 5.0V⎓ (dc) and 20mA represent Range High rh for a process input. The process input is linearly scaled between rL and rH. See the model number and specification information in the Appendix for your range values, or refer to the following table.
Range: Sensor range high to rL
Default: High limit of sensor type for a thermocouple or RTD. 9999 for process input.

Ot1

Output 1: Selects the action for the primary output in response to the difference between set point and process variable. Select ht (heat) for reverse acting or select CL (cool) for direct acting.
Range: ht, CL **Default:** ht

HSC

Hysteresis-Control: Selects the switching hysteresis for Output 1 and 2 when you select 0 (on-off) under the Pb1 parameter and Ot2 is set to Con.
Range: 1 to 55, 0.1 to 5.5, 0.01 to 0.55°C/1 to 99, 0.1 to 9.9, 0.01 to 0.99°F
Default: 2, 0.2, 0.02°C/3, 0.3, 0.03°F

Ot2

Output 2: Selects the output action for the secondary output.
Range:

Con	Control mode opposite Output 1 (heat or cool)
PrA	Process alarm with alarm message displayed
Pr	Process alarm with no alarm message displayed
dEA	Deviation alarm with alarm message displayed
dE	Deviation alarm with no alarm message displayed
no	None

Default: Con

HSA

Hysteresis - Alarm: Selects the switching hysteresis for Output 2 when Ot2 is an alarm. Appears only if Ot2 is not set to Con or no. See the Operation Menu for Pb1.
Range: 1 to 5555, 0.1 to 555.5, 0.01 to 55.5°C/1 to 9999, 0.1 to 999.9, 0.01 to 99.99°F
Default: 2, 0.2, 0.02°C/3, 0.3, 0.03°F

Setup

LAt

Latching: Selects whether the alarm is latching or non-latching. Latching alarms must be cleared by pressing the ∞Infinity key before the alarm output will reset. Selecting non-latching will automatically reset the alarm output when the condition clears. Appears only if Ot2 is not set to Con or no.
Range: LAt or nLA **Default:** nLA

SIL

Silencing: Selects alarm silencing (inhibit) for the alarm. Appears only when Ot2 is set to dEA or dE. For more information see Chapter 5.
Range: On or OFF **Default:** OFF

rtd

RTD: Selects the RTD calibration curve for RTD inputs. Will not appear unless In is set to rtd or rt.d. JIS is 0.003916Ω/Ω°C, din is 0.003850Ω/Ω°C.
Range: din or JIS **Default:** din

rP

Ramping: Choose Str, and the set point ramps at the selected rate in °/hr. from the process (actual) temperature to the set point, when power is applied to the controller (start up). It will not ramp with a set point change. On is the same as Str, but ramps *with* a set point change. It ramps from the previous set point to a new one at the selected ramp rate. Select OFF for no ramping action. When ramping, the lower display alternately flashes rP. The set point displayed is the desired end set point. The ramping set point is not shown. Entering the Setup Menu or manual operation disables the outputs and ramp. Once you exit either one, the Series 93 controls to the last entered set point.
Range: Str, On, OFF **Default:** OFF

rt

Rate: Selects the ramping rate in degrees per hour. Will not appear if rP is set to OFF.
Range: 0 to 9999 **Default:** 100°/hr.

P L

Power Limiting: The power limiting function in % power for heat only. Power Limiting will function if Pb1 is not set to 0.
Range: Dependent on output type. 0 to 100 **Default:** 100

dSP

Display: Selects which displays are active or viewable. Five seconds after selected, the appropriate display goes blank. Press ◉Advance, ⭘Up-arrow or ⭘Down-arrow to override this feature and cause the current value to be displayed for 5 seconds.
Range: nor Normal displays **Default:** nor
SEt Set Point - lower display only
Pro Process - upper display only

Table 4.5a - Input Ranges.

Input Type	Sensor Range Low	Sensor Range High
J	0°C/32°F	750°C/1382°F
H	-200°C/-328°F	1250°C/2282°F
t	-200°C/-328°F	350°C/662°F
n	0°C/32°F	1250°C/2282°F
S	0°C/32°F	1450°C/2642°F
rtd (1°)	-200°C/-328°F	700°C/1292°F
rt.d (0.1°)	-128.8°C/-199.9°F	537.7°C/999.9°F
420	4mA/-999 units	20mA/9999 units
0-5	0V⎓ (dc)/-999 units	5V⎓ (dc)/9999 units

NOTE:

Document your Setup Menu parameters below. Do not mark any values here; make photocopies instead.

Setup Menu

Table 4.5b - Setup Menu Prompts and Descriptions.

Parameter	Value	Range	Factory Default	Appears If:
LOC		0 to 4	0	
In		J, H, t, n, S, rtd, rt.d, 0-5, 420	J	DIP switch selectable.
dEC		0, 0.0, 0.00	0	In is set to 0-5 or 420
C_F		C or F	Dependent on dFL	In is set to J, H, t, n, S, rtd, or rt.d
rL		rL to rh	Input dependent	
rh		rh to rL	Input dependent	
Ot1		ht or CL	ht	
HSC		1 to 55, 0.1 to 5.5, 0.01 to 0.55°C 1 to 99, 0.1 to 9.9, 0.01 to 0.99°F	2, 0.2, 0.02°C 3, 0.3, 0.03°F	
Ot2		Con Control PrA Process alarm Pr Process with no alarm message dEA Deviation alarm dE Deviation with no alarm message no None	Con	
HSA		1 to 5555, 0.1 to 555.5, 0.01 to 55.55°C 1 to 9999, 0.1 to 999.9, 0.01 to 99.99°F	2, 0.2, 0.02°C 3, 0.3, 0.03°F	Ot2 is not set to Con or no
LAt		LAt or nLA	nLA	Ot2 is not set to Con or no
SIL		On or OFF	OFF	Ot2 is set to dEA or dE
rtd		JIS or din	din	In is set to rtd or rt.d
rP		Str Ramping on power up On Ramping to set point at all times OFF None	OFF	
rt		0 to 9999	100°/hr	rP is not set to OFF
PL		0 to 100	100	Ot1 or Ot2 is set to ht
dSP		nor normal SEt Set Point (lower only) Pro Process (upper only)	nor	

Setup

Operation Menu

Entering the Operation Menu

The Operation Menu contains parameters that determine how the controller will control and operate. These are parameters that users may need to change from time to time. The Operation Menu is entered by pressing the ⊛Advance key. The setting of the [LOC] parameter will affect the ability to access this menu.

Figure 4.6 - The Operation Menu.

NOTE:

The upper display will always return to the process value after 1 minute without key strokes.

NOTE:

Shaded parameters may not appear, depending on the controller's configuration and model number.

Operation Menu

- [93] Control Set Point
- [Pb 1] Proportional Band 1
- [rE 1] Reset 1*
- [It 1] Integral 1*
- [rA 1] Rate 1*
- [dE 1] Derivative 1*
- [Ct 1] Cycle Time 1*
- [ALO] Alarm Low*
- [AH 1] Alarm High*
- [Pb2] Proportional Band 2*
- [rE2] Reset 2*
- [It2] Integral 2*
- [rA2] Rate 2*
- [dE2] Derivative 2*
- [Ct2] Cycle Time 2*
- [CAL] Calibration Offset
- [AUt] Autotune

* Parameter may not always appear.

Operation Parameters

Pb 1

Pb2

Proportional Band 1 and 2: A proportional band, expressed in degrees or % of span, within which a proportioning function is active for Output 1 or 2. When [Pb 1] is set to 0, the unit functions as an on-off control on Output 1 and 2. [Pb2] will not appear if [Pb 1] is set to 0 or [Ot2] is not set to [Con]. The switching differential is determined by the [HSC] parameter.
Range if [dFL] is set to [US]: [Pb 1]: 0 to 555°C/0 to 999°F/0 to 999 Units; 0.0 to 55.5°C/0.0 to 99.9°F/0.0 to 99.9 units, [Pb2]: The same as [Pb 1] except lower limit is 1 or 0.1. **Defaults:** [Pb 1] is set to 25°F/2.5°F. [Pb2] is set to 25.
Range if [dFL] is set to [SI]: 0 to 999.9% of span
Defaults: [Pb 1] is set to 3.0% [Pb2] is set to 3.0%

rE 1

It 1

rE2

It2

Reset /Integral 1 and 2: An integral control action for Output 1 or 2 that automatically eliminates offset, or "droop," between set point and actual process temperature. [rE 1]/[It 1]: Will not appear if [Pb 1] is set to 0. [rE2]/[It2]: Appears if [Pb 1] is not set to 0 and [Ot2] is set to [Con]. Either reset [rE] or integral [It] will appear depending on how the [dFL] parameter is set in the Calibration Menu. See the Appendix.
Range if [dFL] is set to [US]: 0 to 9.99 repeats/minute **Default:** 0.00
Range if [dFL] is set to [SI]: 00.1 to 9.99 minutes per repeat **Default:** 0.00

rA 1

dE 1

rA2

dE2

Rate/Derivative 1 and 2: The rate (derivative) function for Output 1 or Output 2.
Eliminates overshoot on startup, or after the set point changes. [rA 1]/[dE 1]: Will not appear if [Pb 1] is set to 0. [rA2]/[dE2]: Appears if [Pb 1] is not set to 0 and [Ot2] is set to [Con]. Either rate [rA] or derivative [dE] appears depending on how [dFL] is set in the Calibration Menu.
Range if [dFL] is set to [US] or [SI]: 0 to 9.99 minutes **Default:** 0.0

Ct 1

Ct2

Cycle Time 1 and 2: Time for a controller to complete one time-proportioned cycle for Output 1 or Output 2; expressed in seconds. [Ct 1]: Will not appear if [Pb 1] is set to 0, or Output 1 is 4-20mA. [Ct2]: Will not appear if [Pb 1] is set to 0 or [Ot2] is not set to [Con].

If a mechanical relay or contactor is switching power to the load, a longer cycle time may be desirable to minimize wear on the mechanical components. Typical life of a mechanical relay is 100,000 cycles.
Range: 0.1 to 999.9 seconds **Default:** 5.0 seconds

[ALO]

Alarm Low: Represents the low process alarm or low deviation alarm. This parameter will not appear if [Ot2] is set to no or [Con].
Range if [Ot2] is set to [dEA] or [dE]: -999 to 0 **Default:** -999
Range if [Ot2] is set to [PrA] or [Pr]: [rL] to [AH1] **Default:** [rL]

[AH1]

Alarm High: Represents the high process alarm or high deviation alarm. This parameter will not appear if [Ot2] is set to [no] or [Con].
Range if [Ot2] is set to [dEA] or [dE]: 0 to 999 **Default:** 999
Range if [Ot2] is set to [PrA] or [Pr]: [ALO] to [rH] **Default:** [rH]

[CAL]

Calibration Offset: Adds or subtracts degrees from the input signal.
Range: -100°C to 100°C/-180°F to 180°F/-180 units to 180 units; or -10.0°C to 10.0°C/-18.0°F to 18.0°F **Default:** 0

[AUt]

Autotune: Initiates an autotune.
Range: 0 is set to off, 1 is set to slow, 2 is set to medium, 3 is set to fast
Default: 0

Table 4.7 - Operation Menu Prompts and Descriptions.

Operation Menu

Document your Series 93 Operation Parameters in the Value column below. Do not mark any values here; make photocopies instead.

Operation Parameters	Value	Range	Factory Default
[Pb1]		If [dFL] is set to [US]: 0 to 555°C/0 to 999°F/0 to 999 Units 0 to 55.5°C/0 to 99.9°F/0 to 99.9 Units 0 is control. [HSC] is set to switch differential If [dFL] is set to [SI]: 0.0 to 999.9% of span	25°F 2.5°F 3%
[rE1]		0.00 to 9.99 repeats/minute 0.00 = No Reset. Won't appear if [Pb1] is set to 0 or [dFL] is set to [SI].	0.00 repeats/minute
[It1]		0.0 to 99.9 minutes/repeat. 0.00 = No Integral. Won't appear if [Pb1] is set to 0 or [dFL] is set to [US].	00.0 minutes/repeat
[rA1]		0.00 to 9.99 minutes 0.00 = No Rate. Will not appear if [Pb1] is set to 0 or [dFL] is set to [SI].	0.00 minutes
[dE1]		0.00 to 9.99 minutes. 0.00 = No Derivative. Won't appear if [Pb1] is set to 0 or [dFL] is set to [US].	0.00 minutes
[Ct1]		0.1 to 999.9 Won't appear if [Pb1] is set to 0, or [420].	5.0 seconds
[Pb2]		Same as [Pb1]. [Pb2] lower limit = 1, 0.1, 0.01	
[rE2]		Same range as [rE1].	
[It2]		Same range as [It1].	
[rA2]		Same range as [rA1].	
[dE2]		Same range as [dE1].	
[Ct2]		Same range as [Ct1].	
[ALO] Deviation [dE] Process [Pr]		-999 to 0 [rL] to [AH1] Will not appear if [Ot2] is set to [no] or [Con].	-999 [rL]
[AH1] Deviation [dE] Process [Pr]		0 to 999 [ALO] to [rH] Will not appear if [Ot2] is set to [no] or [Con].	999 [rH]
[CAL]		±100°C/±180°F/±180 Units	0
[AUt]		0 to 3	0

Setup

Notes

Setup

5 How to Tune and Operate the Series 93

Autotuning (Heat and/or Cool)

NOTE:

Set the HSC parameter under the Setup Menu to 2°C/3°F before autotuning your controller.

The Series 93 can automatically tune the PID parameters to fit the characteristics of your particular thermal system.

The autotuning procedure operates on a thermal response value — slow, medium, or fast. Use the slow thermal response when your process does not need to reach the set point too rapidly, or if it usually does not often exceed the set point. A fast thermal response produces a rapid temperature change over a short period of time.

Once the autotune sequence has begun, the Output 1 heat proportional band is set to 0 and the control goes into an on-off mode of control at 90% of the established set point. The displayed set point remains unchanged.

Once the controller finishes "learning" the system, it returns to a standard PID control with the PID values automatically set as a result of autotuning. Autotune does not change cycle time parameters. The controller can also be manually tuned. See the next page for instructions on how to manually tune the controller. Any change of the set point, while in autotune, re-initiates the autotune procedure.

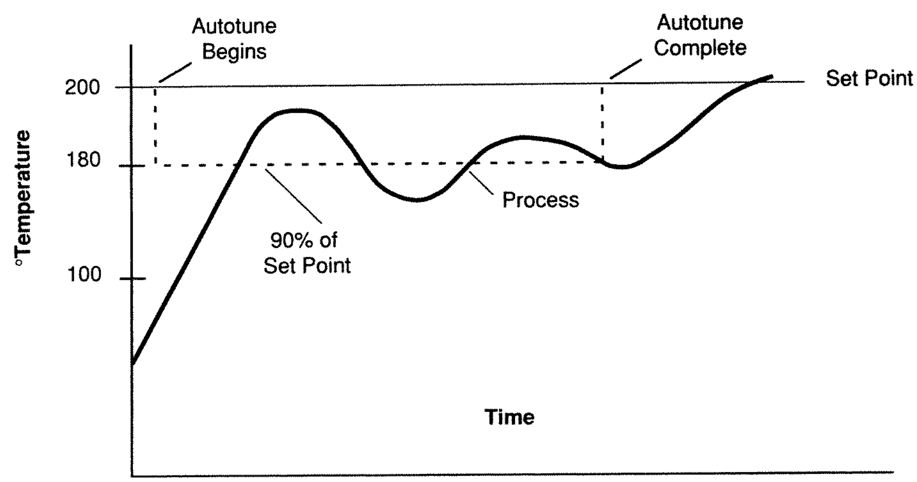


Figure 5.1 - Autotuning at a Set Point of 200°F.

In order for the Series 93 to successfully complete the autotune, the process must cross 90% of the set point four times within 80 minutes after the autotune has started. If this does not happen within the 80-minute time limit, the Pb remains at 0 and the controller functions in an on-off mode.

To start autotuning:

1. **Press the ®Advance key** until the AUt prompt appears in the data display.

2. **Select a thermal response value using the ↑Up-arrow/↓Down-arrow keys:** 1 for a slow response, 2 for an average response and 3 for a system that responds quickly. A thermal response value of 2 satisfactorily tunes most thermal systems.

3. **Press the ®Advance key.** While the controller is in the tuning mode, the lower display alternately displays the normal information and the prompt AUt, at one-second intervals.

Tuning and Operating

4. When tuning is complete, the displays return to their previous state and [AUt] reverts to 0. The Series 93 installs appropriate PID tuning parameters and saves them in the non-volatile memory. **If a mechanical relay or contactor is switching power to the load, a longer cycle time may be desirable to minimize wear on the mechanical components. Typical life of a mechanical relay is 100,000 cycles.**

To abort autotuning either reset the [AUt] parameter to 0, press the ∞Infinity key twice, or cycle power off and on. In all cases, aborting autotune restores all values to those previous to autotuning.

Manual Tuning

NOTE:

Tune heating outputs at a set point above ambient temperature.

Tune cooling outputs at a set point below ambient temperature.

For optimum controller performance, tune the Series 93 to your thermal system. The tuning settings here are for a broad spectrum of applications; your system may have somewhat different requirements. **NOTE: This is a slow procedure, taking from minutes to hours to obtain optimum value.**

1. Apply power to the Series 93 and enter a set point. Set Operation parameters as follows: [Pb] to [1], [rE] / [It] to [0.00], [rA] / [dE] to [0.00], [Ct] to [5.0], [CAL] to [0], [AUt] to [0].

2. Proportional Band Adjustment: Gradually increase [Pb] until the upper display temperature stabilizes to a constant value. The process temperature will not be right on set point because the initial reset value is 0.00 repeats per minute. (When [Pb] is set to 0; [rE] / [It] and [rA] / [dE] are inoperative, and the Series 93 functions as a simple on-off controller.) The [HSC] parameter determines the switching differential value.

3. Reset/Integral Adjustment: Gradually increase [rE], or decrease [It] until the upper display temperature begins to oscillate or "hunt." Then slowly decrease [rE] or increase [It] until the upper display stabilizes again near the set point.

4. Cycle Time Adjustment: Set [Ct] as required. Faster cycle times sometimes achieve the best system control. However, if a mechanical contactor or solenoid is switching power to the load, a longer cycle time may be desirable to minimize wear on the mechanical components. Experiment until the cycle time is consistent with the quality of control you want. [Ct] will not appear on units with a process output.

5. Rate/Derivative Adjustment: Increase [rA] / [dE] to 1.00 minute. Then raise the set point by 11° to 17°C, or 20° to 30°F. Observe the system's approach to the set point. If the load temperature overshoots the set point, increase [rA] / [dE] to 2.00 minutes.

Raise the set point by 11 to 17°C, or 20 to 30°F and watch the approach to the new set point. If you increase [rA] / [dE] too much, the approach to the set point is very sluggish. Repeat as necessary until the system rises to the new set point without overshooting or approaching the set point too slowly.

6. Calibration Offset Adjustment: You may want your system to control to a temperature other than the value coming from the input sensor. If so, measure the difference between that temperature (perhaps at another point in the system) and the process value showing in the upper display. Then enter the calibration offset value you want. Calibration offset adds or subtracts degrees from the value of the input signal.

Tuning and Operating

Manual and Automatic Operation

To change from auto to manual operation, press the Infinity key twice.

Manual operation provides open loop control of the outputs from a range of -100% (full cooling) to 100% (full heating) power. The Series 93 allows a negative output value only when [Ot2] is set to [Con]. Automatic operation provides closed-loop on-off or PID control. When the operator transfers from a closed-loop to an open loop, the Series 93 retains the power level from the closed-loop control, referred to as bumpless transfer. When the Series 93 returns to closed-loop control, it restores the previous set point temperature.

The percent indicator light indicates auto or manual operation. When the percent indicator light is on, the control is in manual operation and displays the percent power value in the lower display. When the percent indicator light is off, it is in automatic operation. Press the Infinity key to flash the percent indicator light. Press the Infinity key again to complete the manual/automatic change.

When a sensor opens, the Series 93 switches from automatic to manual operation if [LOC] is set to 0, 1 or 2.

- If [LOC] is set to 0, 1 or 2 and the bumpless transfer conditions are met, the Series 93 switches to manual operation at the last automatic power level. The bumpless transfer conditions are: the process has stabilized within a ± 5% power level for at least two minutes prior to sensor break provided the power level is less than 75%.
- If [LOC] is set to 3 or 4, the Series 93 switches into manual operation at 0% power (outputs disabled).

NOTE:

A process input does not have sensor break protection or bumpless transfer. Outputs selected as [ht] (reverse acting) will be full on if a sensor break occurs.

When transferring from auto to manual operation, the controller output(s) remains stable ("bumpless," smooth transition). When transferring from manual to automatic operation, the controller output(s) may change significantly. In manual operation, the percent output power set point appears in the lower display; in automatic operation, the control set point appears.

Setting the Control Set Point

The set point sets the operating set point for the control output(s). It represents the process value the system tries to achieve. The control set point value is displayed in the lower display window while in the auto mode of operation. The set point can be incremented or decremented without pressing the Advance key. The lower display may be blank if [dSP] is set to [Pro]. In ramping mode, the lower display alternately flashes the desired end set point and [rP]. The setting of the [LOC] parameter can limit the ability to change the set point.

To change the set point, press either the Up-arrow/Down-arrow keys to increment or decrement the set point value. Any change will automatically be entered after three seconds.

Using Alarms

The Series 93 has two alarm types, process and deviation.

A **process alarm** sets an absolute temperature. When the process exceeds that absolute temperature limit an alarm occurs. The process alarm set points may be independently set high and low. Under the Setup Menu, select the type of alarm output with the [Ot2] parameter. [PrA] sets a process alarm with an alarm message displayed. [Pr] sets a process alarm with no alarm message displayed.

NOTE:

When the alarm output is de-energized, the N.O. contact is open in the alarm condition. The N.C. contact is closed in the alarm condition.

A **deviation alarm** alerts the operator when the process strays too far from the set point. The operator can enter independent high and low alarm settings. The reference for the deviation alarm is the set point. Any change in set point causes a corresponding shift in the deviation alarm. [dEA] sets a deviation alarm with an alarm message displayed. [dE] sets a deviation alarm with no alarm message displayed

Example: If your set point is 100°F, and a deviation alarm is set at +7°F as the high limit, and -5°F as the low limit, the high alarm trips at 107°F, and the low alarm at 95°F. If you change the set point to 130°F, the alarms follow the set point and trip at 137°F and 125°F.

Latching: Both process and deviation alarms can be latching or non-latching. When the alarm condition is removed a **non-latching alarm automatically** clears the alarm output. You must **manually clear a latching alarm** before it will disappear.

Flashing [LO] or [HI] in the lower display indicates an alarm when [Ot2] is set to [PrA] or [dEA]. The lower display alternately shows information from the current parameter and the [LO] or [HI] alarm message at one-second intervals. The alarm output is de-energized and the Output 2 indicator light is lit.

To clear an alarm...

- First correct the alarm condition, then…
  - **If the alarm is latching...**
    Clear it manually; press the ∞Infinity key once as soon as the process temperature is inside the [HSA] parameter alarm limit.
  - **If the alarm is non-latching...**
    The alarm clears itself automatically as soon as the process temperature is inside the [HSA] parameter alarm limit.

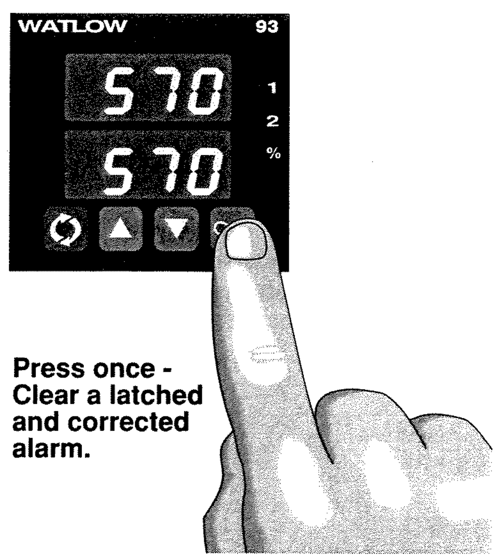


Figure 5.4 - Clearing an Alarm.

Alarm Silencing is available with the deviation alarm and has two uses:

When [SIL] is selected as "on," the operator must manually disable the alarm by pressing the ∞Infinity key once on initial power up (in either the latching or non-latching mode). Alarm silencing disables the alarm output relay. However, the Output 2 indicator light (also the lower display when [Ot2] is set to [dEA]) shows an alarm condition until the process value is within the "safe" region of the deviation alarm band. Once the process value crosses into the "safe" region, both a latching or a non-latching alarm is ready. Any future deviation outside this safe band triggers an alarm.

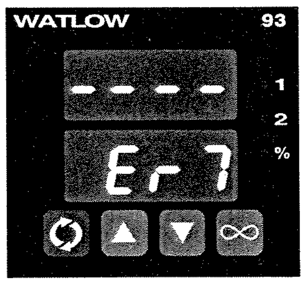
Error Code Messages

NOTE:

An alarm display will be masked by an error condition or when the controller is in the Calibration or Setup Menus.

Four dashes [----] in the upper display indicate a Series 93 error. The error code is visible in the lower display.

Figure 5.5 - Error Code Message.



[Er2] - **Sensor underrange error (applies only to RTD units)**
The sensor input generated a value lower than the allowable signal range, or the analog-to-digital circuitry malfunctioned. Enter a valid input. Make sure the [In] parameter (Setup Menu) and the DIP switch settings both match your sensor.

[Er4] - **Configuration error**
The controller's microprocessor is faulty; call the factory.

[Er5] - **Nonvolatile checksum error**
The nonvolatile memory checksum discovered a checksum error. Unless a momentary power interruption occurred while the controller was storing data, the nonvolatile memory is bad. Call the factory.

[Er6] - **Analog-to-digital underflow error**
The analog-to-digital circuit is underrange. An open or reversed polarity sensor is the most likely cause. Check the sensor; if the connection is good and functions properly, call the factory. The analog-to-digital underrange voltage is too low to convert an analog-to-digital signal. Make sure the [In] parameter (Setup Menu) matches your sensor and the DIP switches are set accordingly.

[Er7] - **Analog-to-digital overflow error**
The analog-to-digital circuit is overrange. An open or reversed polarity sensor is the most likely cause. Check the sensor; if the connection is good, and the sensor functions properly, call the factory. The analog-to-digital overrange voltage is too high to convert an analog-to-digital signal. Make sure the [In] parameter (Setup Menu) matches your sensor and the DIP switches are set accordingly.

⚠ **CAUTION:**

Electrical noise or a noise event, vibration or excess environmental moisture or temperature may cause Series 93 errors to occur. If the cause of an error is not otherwise apparent, check for these.

Error Code Actions

- Er2, Er6, Er7 **result in these conditions:**
  - **If LOC Lock is set to 0, 1 or 2:**
    ...and the controller was in automatic operation when the error occurred, it goes into manual (% power) operation. If the output power is less than 75% power, and a <5% change in power occurred within the last two minutes, the Series 93 switches into manual operation at the last automatic power level (bumpless transfer). If the controller was in manual operation, it remains there. Press the ∞Infinity key twice to see the error code. The alarm output (if present) is in its alarm state (indicator lit). The upper display reads ----. The lower display indicates the error code if the ∞Infinity Key is pressed twice.

    If the controller was operating with stable output values when the error occurred, it continues to operate at those levels on a % power basis. If output values were not stable, the control outputs go to 0% power (off).
  - **If LOC Lock is set to 3 or 4:**
    The controller remains in automatic operation and the outputs turn off. The ∞Infinity and ⊛Advance keys are inactive. The ▲Up-arrow/▼Down-arrow keys may be pressed simultaneously to enter the Setup Menu. The alarm output (if present) is in its alarm state (indicator light lit). The upper display reads ----. The lower display indicates the error code if the ∞Infinity key is pressed.
  - **To clear a corrected error...**
    - Press the ⊛Advance key or turn the controller off and on.

- Er4 **and** Er5 **result in these conditions:**
  - The controller is in automatic operation with both outputs off.
  - The alarm output, if present, are in their alarm state (de-energized with the indicator lit).
  - The upper display indicates the process value.
  - The lower display indicates the error code.
  - All keys are inactive.
  - All Setup Menu parameters return to default values.
  - The above conditions occur regardless of the value of LOC, or the presence of the Setup or Calibration Menus.
  - **To clear a corrected error...**
    - Turn the controller off and on.

Tuning and Operating

A Appendix

Noise and Installation Guidelines

For wiring guidelines, refer to the IEEE Standard No. 518-1982, available from IEEE, Inc. 345 East 47th Street, New York, NY 10017.

Noise Sources

- Switches and relay contacts operating inductive loads such as motors, coils, solenoids, and relays, etc.
- Thyristors or other semiconductor devices which are not zero crossover-fired (randomly-fired or phase angle-fired devices).
- All welding machinery and heavy current carrying conductors.
- Fluorescent and neon lights.

Decreasing Noise Sensitivity

- Physical separation and wire routing must be given careful consideration in planning the system layout. For example, ac power supply lines should be bundled together and physically kept separate from input signal lines (sensor lines). A 305-mm (12-inch) minimum separation is usually effective. Keep all switched output signal lines (high power level) separate from input signal lines (sensor lines). Cross other wiring at 90° angles whenever crossing lines is unavoidable.

- Look at the system layout; identify and locate electrical noise sources such as solenoids, relay contacts, motors, etc. Route the wire bundles and cables as far away as possible from these noise sources. Don't mount relays or switching devices close to a microprocessor controller. Don't have phase angle-fired devices in the same electrical enclosure or on the same power line with the controller.

- Shielded cables should be used for all low power signal lines to protect them from magnetic and electrostatic coupling of noise. Some simple pointers are:
  - ◊ Whenever possible, run low-level signal lines unbroken from signal source to the controller circuit.
  - ◊ Connect the shield to the controller circuit common at the controller end only. Never leave the shield unconnected at both ends. Never connect both shield ends to a common or ground.
  - ◊ Maintain shield continuity at daisy chain connection points by reconnecting the broken shield.
  - ◊ Assume no electrostatic shielding when using the shield as a signal return. If you must do this, use triaxial cable (electrostatically shielded coaxial cable).

- Use twisted pair wire any time controller circuit signals must travel more than two feet, or when you bundle them in parallel with other wires.
- Select the size or gauge of wire by calculating the maximum circuit current and choosing the gauge meeting that requirement. Using greatly larger wire sizes than required generally increases the likelihood of electrostatic (capacitance) coupling of noise.
- Eliminate ground loops in the entire controller system. You can spot the obvious loops by studying the "as-built" wiring diagram. There are also not-so-obvious ground loops resulting from connecting internal circuit commons in the manufacturer's equipment.
- Do not daisy chain ac power (or return) lines, or output signal (or return) lines to multiple controller circuits. Use a direct line from the power source to each input requiring ac power. Avoid paralleling L1 (power lead) and L2 (return lead) to load power solenoids, contactors, and controller circuits. If an application uses L1 (power lead) to switch a load, L2 (return lead) has the same switched signal and could couple unwanted noise into a controller circuit.
- Tie all ground terminals together with one lead (usually green wire) tied to ground at one point. Don't connect the ground to the controller case if the controller is in a grounded enclosure (preventing ground loops).
- Do not confuse chassis grounds (safety ground) with controller circuit commons or with ac supply L2 (return or neutral line). Each return system wiring must be separate. Absolutely never use chassis ground (safety) as a conductor to return circuit current.

Eliminating Noise

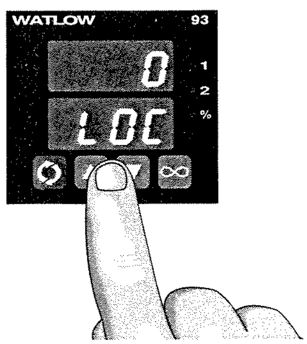
- Use "snubbers" (QUENCHARC™ P/N: 0804-0147-0000) to filter out noise generated by relays, relay contacts, solenoids, motors, etc. A snubber is a simple filter device using a 0.1µf, 600 volt, non-polarized capacitor in series with a 100Ω, 1/2 watt resistor. The device can be used on ac or dc circuits to effectively dampen noise at its source. Refer to output wiring in Chapter Two for proper Quencharc installation.
- The ultimate protection is an "uninterruptable" power supply. This "senses" the ac power line; when the line fluctuates, a battery-powered 60Hz inverted circuit takes over, supplying power within one-half to one cycle of the ac line.

Calibration

Before attempting to calibrate, make sure you read through the procedures carefully and have the proper equipment called for in each procedure. Make sure the DIP switches are in the proper position for the input type. See Chapter Four.

Entering the Calibration Menu

In the Calibration Menu, various input signals must be supplied for the controller to go through its auto calibration. The Calibration Menu can only be entered from the [LOC] Lock parameter in the Setup Menu. Press the ▲Up-arrow/▼Down-arrow keys simultaneously for 3 seconds (± 1 second). The [CAL] parameter appears in the lower display with "no" in the upper display.



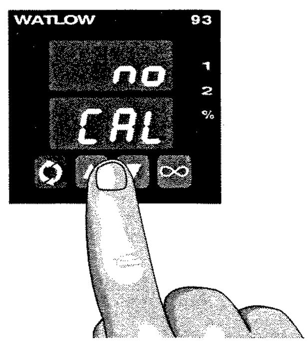


Figure A.3 - Entering the Calibration Menu.

NOTE:
Calibration values will not be retained unless you are in the MANUAL mode. Do not enter the MANUAL mode until you are at the correct input parameters.

Any inadvertent change in the displayed data, when pressing the ▲Up-arrow/▼Down-arrow keys, is ignored. Calibration values won't be retained unless you are in the manual mode. Press the ▲Up-arrow or ▼Down-arrow key to change the upper display to [YES] Press ◉Advance to enter the calibration sequence.

Upon entering the calibration menu, the upper display window indicates [CAL]. It continues to indicate [CAL] (with the exception of calibration of the 4-20mA output) while the operator walks through the entire calibration parameter list. While calibrating the 4-20mA output, the upper display contains a numeric value to be slewed up or down until the output value is correct. The controller uses the lower display to prompt the user as to what the input should be.

With the [dFL] parameter, select either [SI] (System International) and the displayed parameters are °C, integral, derivative and proportional band in % of span. Or select [US] parameters which include displaying °F, rate, reset and proportional band in degrees or units.

NOTE:
While in the Calibration Menu, the controller output(s) go off and the alarm output (if present) is on.

Once the information has been properly established and maintained for at least 5 to 10 seconds, the ◉Advance key may then be used to display the next prompt. After the final input is established, press the ◉Advance key twice to return the controller to the configuration menu at the top of the parameter list.

Appendix

Restoring Factory Calibration

The [rSt] parameter restores the factory calibration values to the Series 93. If you calibrate your controller incorrectly, you have the option to default to the original values. Once you leave the [CAL] menu, the values are entered.

1. Press the Up-arrow/Down-arrow keys simultaneously for three seconds. The LOC parameter appears in the lower display. Continue holding the Up-arrow/Down-arrow keys until the lower display reads [CAL].
2. Press the Up-arrow key until [YES] appears in the upper display.
3. Advance through the Calibration Menu until [rSt] appears in the lower display.
4. Press the Up-arrow key until [YES] appears in the upper display.
5. Press the Advance key and the Series 93 advances to test the displays.
6. To conclude, wait 60 seconds or press the Advance key to reach the next prompt or to exit from the CAL menu.

This procedure is used only to restore calibration, it is not meant to clear values.

Calibration Menu

Calibration Menu

[no] [YES]
[CAL] [CAL]

Prompt	Description
0.00	Input 0.00mV for low input.
50.0	Input 50.00mV for high input.
tC	Connect a Type "J" ambient compensator with inputs shorted.
440	Set the low resistance to 44.01Ω.
255	Set the high resitance to 255.42Ω.
0.00	Set the voltage source to 0.000 volts.
5.00	Set the voltage source to 5.000 volts.
4.00	Set the current source to 4.00mA
20.0	Set the current source to 20.00mA
4A0	Enter 4-20mA output calibration value for 4mA
2A0	Enter 4-20mA output calibration value for 20mA
rSt	Restores factory calibration values.
dSP	Test display.
dFL	Select SI (integral, derivative, proportional band in % of span, °C) or US (rate, reset, proportional band in degrees or units, °F)

Figure A.4 - Calibration Parameters.

Before attempting to calibrate, make sure you have the proper equipment called for in each procedure.

The Series 93 is calibrated and tested before leaving the factory.

Thermocouple Field Calibration Procedure

NOTE:
Before calibrating an installed controller, make sure all data and parameters are documented. See the Setup and Operation Tables in Chapter Four.

Equipment Required

- Type "J" Reference Compensator with reference junction at 0°C/32°F, or Type "J" Thermocouple Calibrator set at 0°C/32°F.
- Precision millivolt source, 0-50mV min. range, 0.01mV resolution

Setup And Calibration

1. Connect the ac line voltage L1 and L2 to the proper terminals.
2. Connect the millivolt source to Terminal 5 Negative and Terminal 3 Positive on the Series 93 terminal strip. Use regular 20 - 24 gauge wire. Make sure the DIP switch is set for thermocouple input. See Chapter Four.
3. Apply power to the controller and allow it to warm up for 15 minutes. **After warm-up** put the controller in the Calibration Menu. See Figure A.3. Select [YES].
4. Press the ⊙Infinity key twice to enter the manual mode. The controller is calibrating when % indicator light is on. Make sure the controller is in manual mode only when you are in the correct parameters.
5. At the 0.00 prompt, enter 0.00mV from the millivolt source to the controller. Allow at least 10 seconds to stabilize. Press the ⊛Advance key.
6. At the 50.0 prompt, enter 50.00mV from the millivolt source to the Series 93. Allow at least 10 seconds to stabilize. Press the ⊛Advance key.
7. At the [tC] prompt, disconnect the millivolt source, and connect the reference compensator or thermocouple calibrator to Terminal 5 Negative, and Terminal 3 Positive on the Series 93 terminal strip. If using a compensator, turn on and short the input wires. If using the "J" calibrator, set it to simulate 0°C/32°F. Allow 10 seconds for the controller to stabilize. The controller will leave the [CAL] mode if one minute passes between key activations. To conclude the thermocouple calibration, press the ⊙Infinity key twice, then press the ⊛Advance key to reach the next prompt or to exit from the [CAL] menu.

RTD Field Calibration Procedure

NOTE:
When the % indicator light is on, the controller is automatically calibrating. Your sequence is VERY important. Always move to the next parameter before changing the calibration equipment.

Equipment Required

- 1KΩ precision decade resistance box with 0.01Ω resolution.

Setup And Calibration

1. Connect the ac line voltage L1 and L2 to the proper terminals.
2. Connect the decade resistance box to Terminal 2, 3 and 5 on the terminal strip. Use regular 20 - 24 gauge wire of the same length and type. Make sure the DIP switch is set for RTD input, see Chapter Four.
3. Apply power to the controller and allow it to warm up for 15 minutes. **After warm-up** put the controller in the [CAL] menu. See Figure A.3. Select [YES]. Press the ⊛Advance key until the **440** prompt is displayed.
4. Press the ⊙Infinity key twice to enter the manual mode. The controller is calibrating when the % indicator light is on. Make sure the controller is in manual mode only when you are in the correct parameters.
5. At the **440** prompt, set the decade resistance box to 44.01. Allow at least 10 seconds to stabilize. Press the ⊛Advance key.
6. At the **255** prompt, set the decade resistance box to 255.42. Allow at least 10 seconds to stabilize. Press the ⊙Infinity key twice to exit the manual mode. The controller will leave the [CAL] mode if one minute passes between key activations. To conclude the RTD calibration, press the ⊙Infinity key twice, then press the ⊛Advance key to reach the next prompt or to exit from the [CAL] menu.

0-5 Volt Input Field Calibration Procedure

NOTE:
Before calibrating an installed controller, make sure all data and parameters are documented. See the Setup and Operation Tables in Chapter Four .

Equipment Required
- Precision dc voltage source 0-5 volt minimum range with 0.001 volt resolution.

Setup and Calibration
1. Connect the ac line voltage L1 and L2 to the proper terminals on the Series 93.
2. Connect the voltage/current source to Terminal 3 (+) and 5 (-) on the Series 93 terminal strip. Use regular 20 - 24 gauge wire. Make sure the DIP switch is set for process input, see Chapter Four.
3. Apply power to the controller and allow it to warm up for 15 minutes. **After warm-up** put the controller in the [CAL] menu. See Figure A.3. Select [YES]. Press the ⊛Advance key until **0.00** is displayed.
4. Press the ⊝Infinity key twice to enter the manual mode. The controller is calibrating when the % indicator light is on. Make sure the controller is in the manual mode **only** when you are in the correct parameters.
5. At the **0.00** parameter, set the voltage source to 0.000 volts. Allow at least 10 seconds to stabilize. Press the ⊛Advance key.
6. At the **5.00** parameter, set the voltage source to 5.000V⎓ (dc). Allow at least 10 seconds to stabilize. The controller leaves the [CAL] mode if 1 minute passes between key activations. Press the ⊝Infinity key twice to exit the manual mode. To conclude the 0-5 volt calibration, press the ⊝Infinity key twice, then press the ⊛Advance key to reach the next prompt or to exit from the [CAL] menu.

4-20mA Input Field Calibration Procedure

NOTE:
When the % indicator light is on, the controller is automatically calibrating. Your sequence is VERY important. Always move to the next parameter before changing the calibration equipment.

Equipment Required:
- Precision current source 0-20mA minimum range with 0.01mA resolution.

Setup and Calibration
1. Connect the ac line voltage L1 and L2 to the proper terminals on the Series 93.
2. Connect the current source to Terminal 2 (-) and 5 (+) on the Series 93 terminal strip. Use regular 20 - 24 gauge wire. Make sure the DIP switch is set for process input, see Chapter Four.
3. Apply power to the controller and allow it to warm up for 15 minutes. **After warm-up** put the controller in the [CAL] menu. See Figure A.3. Select **YES**. Press the ⊛Advance key until **4** is displayed.
4. Press the ⊝Infinity key twice to enter the manual mode. The controller is calibrating when the % indicator light is on. Make sure the controller is in the manual mode **only** when you are in the correct parameters.
5. At the **4.00** parameter, set the current source to 4.00mA. Allow at least 10 seconds to stabilize. Press the ⊛Advance key.
6. At the **20.0** parameter, set the current source to 20.00mA. Allow at least 10 seconds to stabilize. The controller leaves the [CAL] mode if 1 minute passes between key activations. Press the ⊝Infinity key twice to exit the manual mode. To conclude, press the ⊝Infinity key twice, then press the ⊛Advance key to reach the next prompt or to exit from the [CAL] menu.

Appendix

4-20mA Output Field Calibration Procedure

NOTE:
Before calibrating an installed controller, make sure all data and parameters are documented. See the Setup and Operation Tables in Chapter Four.

NOTE:
When the % indicator light is on, the controller is automatically calibrating. Your sequence is VERY important. Always move to the next parameter before changing the calibration equipment.

Equipment Required:

- 300Ω, 1/2 watt 10% resistor.
- 4 - 1/2 digit Digital Multimeter.

Setup And Calibration

1. Connect the ac line voltage L1 and L2 to the proper terminals of the Series 93. See Chapter Two. Set the multimeter to measure current.
2. Connect the multimeter in series with the 300Ω resistor to Terminal 9 Positive and 10 Negative on the Series 93 terminal strip. Use regular 20 - 24 gauge wire.
3. Apply power to the controller and allow it to warm up for 15 minutes. **After warm-up** put the controller in the [CAL] menu. See Figure A.3. Select **YES**. Press the Advance key until the 4A0 prompt is displayed.
4. Press the Infinity key twice to enter the manual mode. The controller is calibrating when the % indicator light is on.
5. At the [4A0] prompt, the multimeter should read approximately 4mA. Allow at least 10 seconds to stabilize.
6. Use the Up-arrow/Down-arrow keys (reverse acting) to adjust the reading on the multimeter for 3.85mA ± 0.10mA. Press the Advance key.
7. At the [20A0] prompt, the multimeter should read approximately 20mA. Allow at least 10 seconds to stabilize. The controller will leave the [CAL] mode if one minute passes between key activations, except for 4-20mA units.
8. Use the Up/Down keys (reverse acting) to adjust the reading on the multimeter for 20.15mA ±0.10mA.
9. To conclude the 4-20mA output calibration, press the Infinity key twice, then press the Advance key to reach the next prompt or to exit from the [CAL] menu.

Appendix

Notes

Appendix

Glossary

A

alarm A signal that indicates that the process has exceeded or fallen below the set or limit point. For example, an alarm may indicate that a process is too hot or too cold.

alarm, deviation Warns that a process has exceeded or fallen below a certain range around the set point. Alarms can be referenced at a fixed number of degrees, plus or minus, from set point.

alarm hysteresis A change in the process variable required to re-energize the alarm output.

alarm silence A feature that disables the alarm relay output.

anti-reset A control feature that inhibits automatic reset action outside the proportional band. Also called anti-reset windup.

anti-reset windup The feature of a PID temperature controller that prevents the integral (automatic reset) circuit from functioning when the temperature is outside the proportional band. This standard feature helps stabilize a system. Also called anti-reset.

automatic prompts Data entry points where a microprocessor-based controller asks the operator to enter a control value.

B

bumpless transfer A smooth transition from auto (closed loop) to manual (open loop) operation. The control output(s) does not change during the transfer.

C

calibration offset An adjustment to eliminate the difference between the indicated value and the actual process value.

CE A manufacturer's mark that demonstrates compliance with European Union (EU) laws governing products sold in Europe.

CE-compliant Compliant with the essential requirements of European directives pertaining to safety and/or electromagnetic compatibility.

closed loop A control system that uses a sensor to measure a process variable and makes decisions based on that input.

cold junction See junction, cold.

cold junction compensation Electronic means to compensate for the effective temperature at the cold junction.

compensation, ambient The ability of an instrument to adjust for changes in the temperature of the environment and correct the readings. Sensors are most accurate when maintained at a constant ambient temperature. When temperature changes, output drifts.

control action The response of the control output relative to the error between the process variable and the set point. For reverse action (usually heating), as the process decreases below the set point, the output increases. For direct action (usually cooling), as the process increases above the set point, the output increases.

cycle time The time required for a controller to complete one on-off-on cycle. It is usually expressed in seconds.

D - E

default parameters The programmed instructions that are permanently stored in the microprocessor software.

derivative The rate of change in a process variable. Also known as rate. See PID.

derivative control (D) The last term in the PID control algorithm. Action that anticipates the rate of change of the process, and compensates to minimize overshoot and undershoot. Derivative control is an instantaneous change of the control output in the same direction as the proportional error. This is caused by a change in the process variable (PV) that decreases over the time of the derivative (TD). The TD is in units of seconds.

Deutsche Industrial Norm (DIN) A set of technical, scientific and dimensional standards developed in Germany. Many DIN standards have worldwide recognition.

deviation alarm See alarm, deviation.

DIN See Deutsche Industrial Norm.

direct action An output control action in which an increase in the process variable causes an increase in the output. Cooling applications usually use direct action.

display capability In an instrument with digital display, the entire possible span of a particular parameter or value.

droop In proportional controllers, the difference between set point and actual value after the system stabilizes.

duty cycle The percentage of a cycle time in which the output is on.

Appendix

F - G

Form A A single-pole, single-throw relay that uses only the normally open (NO) and common contacts. These contacts close when the relay coil is energized. They open when power is removed from the coil.

Form C A single-pole, double-throw relay that uses the normally open (NO), normally closed (NC) and common contacts.

H

hysteresis A change in the process variable required to re-energize the control or alarm output. Sometimes called switching differential.

I

integral Control action that automatically eliminates offset, or droop, between set point and actual process temperature. See reset, automatic.

integral control (I) A form of temperature control. The I of PID. See integral.

isolation Electrical separation of sensor from high voltage circuitry. Allows use of grounded or ungrounded sensing element.

J - K

JIS See Joint Industrial Standards.

Joint Industrial Standards (JIS) A Japanese agency that establishes and maintains standards for equipment and components. Also known as JISC (Japanese Industrial Standards Committee), its function is similar to Germany's Deutsche Industrial Norm (DIN).

junction The point where two dissimilar metal conductors join to form a thermocouple.

junction, cold Connection point between thermocouple metals and the electronic instrument. See reference junction.

junction, reference The junction in a thermocouple circuit held at a stable, known temperature (cold junction). Standard reference temperature is 32°F (0°C).

L

limit or limit control A highly reliable, discrete safety device (redundant to the primary controller) that monitors and limits the temperature of the process, or a point in the process. When temperature exceeds or falls below the limit set point, the limit controller interrupts power through the load circuit. A limit control can protect equipment and people when it is correctly installed with its own power supply, power lines, switch and sensor.

M

manual mode A selectable mode that has no automatic control aspects. The operator sets output levels.

N

NEMA 4X A NEMA specification for determining resistance to moisture infiltration and corrosion resistance. This rating certifies the controller as washable and corrosion resistant.

O

offset (process) The difference in temperature between the set point and the actual process temperature. Offset is the error in the process variable that is typical of proportional-only control. See also droop.

on/off A method of control that turns the output full on until set point is reached, and then off until the process error exceeds the hysteresis.

open loop A control system with no sensory feedback.

output Control signal action in response to the difference between set point and process variable.

overshoot The amount by which a process variable exceeds the set point before it stabilizes.

P - Q

P control Proportioning control.

parallel circuit A circuit configuration in which the same voltage is applied to all components, with current divided among the components according to their respective resistances or impedances.

parameter A variable that is given a constant value for a specific application or process.

PD control Proportioning control with derivative (rate) action.

percent power control Open loop control with output power set at a particular level.

percent power limit Restriction of output power to a predetermined level.

PI control Proportioning control with integral (automatic reset) action.

PID Proportional, integral, derivative. A control mode with three functions: proportional action dampens the system response, integral corrects for droop, and derivative prevents overshoot and undershoot.

process variable The parameter that is controlled or measured. Typical examples are temperature, relative humidity, pressure, flow, fluid level, events, etc. The high process variable is the highest value of the process range, expressed in engineering units. The low process variable is the lowest value of the process range.

programmed display data Displayed information that gives the operator the intended process information, such as intended set point, intended alarm limit, etc., corresponding to temperature.

prompt A symbol or message displayed by the controller that requests input from the user.

proportional Output effort proportional to the error from set point. For example, if the proportional band is 20° and the process is 10° below set point, the heat proportioned effort is 50 percent. The lower the PB value, the higher the gain.

proportional band (PB) A range in which the proportioning function of the control is active. Expressed in units, degrees or percent of span. See PID.

proportional control A control using only the P (proportional) value of PID control.

R

rate Anticipatory action that is based on the rate of temperature change, and compensates to minimize overshoot and undershoot. See derivative.

reference junction See junction.

reset Control action that automatically eliminates offset, or droop, between set point and actual process temperature. Also see integral.

reset, automatic The integral function of a PI or PID temperature controller that adjusts the process temperature to the set point after the system stabilizes. The inverse of integral.

reset windup inhibit See anti-reset.

resistance temperature detector (RTD) A sensor that uses the resistance temperature characteristic to measure temperature. There are two basic types of RTDs: the wire RTD, which is usually made of platinum, and the thermistor, which is made of a semiconductor material. The wire RTD is a positive temperature coefficient sensor only, while the thermistor can have either a negative or positive temperature coefficient.

reverse action An output control action in which an increase in the process variable causes a decrease in the output. Heating applications usually use reverse action.

RTD See resistance temperature detector.

S

set point The desired value programmed into a controller. For example, the temperature at which a system is to be maintained.

switching sensitivity In on/off control, the temperature change necessary to change the output from full on to full off. See hysteresis.

T - Y

thermal system A regulated environment that consists of a heat source, heat transfer medium or load, sensing device and a control instrument.

thermocouple (t/c) A temperature sensing device made by joining two dissimilar metals. This junction produces an electrical voltage in proportion to the difference in temperature between the hot junction (sensing junction) and the leadwire connection to the instrument (cold junction).

thermocouple break protection The ability of a control to detect a break in the thermocouple circuit and take a predetermined action.

three-mode control Proportioning control with integral (reset) and derivative (rate). Also see PID.

time proportioning control A method of controlling power by varying the on/off duty cycle of an output. This variance is proportional to the difference between the set point and the actual process temperature.

triac A solid state device that switches alternating current.

Z

zero cross Action that provides output switching only at or near the zero-voltage crossing points of the ac sine wave. See burst fire.

zero switching See zero cross.

Specifications

Specifications (2218)

Control Mode
- Microprocessor-based, user-selectable control modes
- Single input, dual output
- 2.5Hz Input Sampling Rate
- 1Hz Display Update Rate
- Ramp to set point: 0 to 9999 degrees or units per hour
- Heat and cool autotune

Operator Interface
- Sealed membrane front panel
- Dual, four-digit red or green displays
- Advance, Up-arrow, Down-arrow, and Infinity keys
- User-selectable screen display

Accuracy
- Calibration accuracy and sensor conformity: ±0.1% of span, ±1°C @ 25°C ± 3°C (77°F ± 5°F) ambient and rated line voltage
- Accuracy span: 540°C (1000°F) minimum
- Temperature stability: ±0.2°C/°C (±0.2°F/°F) rise in ambient maximum

Sensors/Inputs
- Thermocouple, grounded or ungrounded sensors
- RTD 2- or 3-wire, platinum, 100Ω @ 0°C calibration to DIN curve (0.00385Ω/Ω/°C) or JIS curve (0.003916Ω/Ω/°C); user-selectable
- Process, 4-20mA @ 5Ω, or 0-5V⎓ (dc) @ 10kΩ input impedance
- Sensor break protection de-energizes control output to protect system or selectable bumpless transfer to manual operation
- °C or °F or process units display, user-selectable

Input Range

Specified temperature ranges represent the controller's operational span.

• Thermocouple

Type J	0	to	750°C
	(32	to	1382°F)
Type K	-200	to	1250°C
	(-328	to	2282°F)
Type N	0	to	1250°C
	(32	to	2282°F)
Type S	0	to	1450°C
	(32	to	2642°F)
Type T	-200	to	350°C
	(-328	to	662°F)

• RTD Resolution (DIN or JIS)

1°	-200	to	700°C
	(-328	to	1292°F)
0.1°	-128.8	to	537.7°C
	(-199.9	to	999.9°F)

• Process

4-20mA @ 5Ω, or -999 to 9999 units
0-5V (dc) @ 10kΩ, or -999 to 9999 units

Output 1 (Heating or Cooling)
- Electromechanical relay[1], Form C, 5A @ 120/240V~ (ac) maximum, without contact suppression, rated resistive load, 5A @ 30V⎓ (dc)[2]. Minimum contact current, 100mA @ 5V⎓ (dc).
- Switched dc signal provides a non-isolated minimum turn on voltage of 3V⎓ (dc) into a minimum 500Ω load; maximum on voltage not greater than 12V⎓ (dc) into an infinite load.
- 4-20mA reverse or direct acting, non-isolated 0 to 800Ω load.
- Solid-state relay[2], Form A, 0.5A @ 24V~ (ac) min., 264V~ (ac) max., opto-isolated burst fire switched, without contact suppression. Off-state output impedance is 31MΩ.

Output 2 (Heat, Cool or Alarm)
- Electromechanical relay[1], Form C, 5A @ 120/240V~ (ac) maximum, without contact suppression, rated resistive load, 5A @ 30V⎓ (dc)[2]. Minimum contact current, 100mA @ 5V⎓ (dc).
- Switched dc signal provides a non-isolated minimum turn on voltage of 3V⎓ (dc) into a minimum 500Ω load; maximum on voltage not greater than 12V⎓ (dc) into an infinite load.
- Solid-state relay[2], Form A, 0.5A @ 24V~ (ac) min., 264V~ (ac) max., opto-isolated burst fire switched, without contact suppression. Off-state output impedance is 31MΩ.
- Alarm output can be latching or non-latching, and process or deviation with separate high and low values. Alarm silencing (inhibit) on power up (for deviation alarms only).

Output Configurations

• Output 1

User-selectable as: on-off: P, PI, PD, PID, heat or cool action
- Adjustable switching differential: 1 to 55°C (1 to 99°F)
- Proportional band: 0 (off) or 0 to 555°C (1 to 999°F) or 0.0 to 999.9 units
  Integral: 0 (off) or 0.1 to 99.9 minutes per repeat
  Reset: 0 (off) or 0.01 to 9.99 repeats per minute
  Rate/derivative: 0 (off) or 0.01 to 9.99 minutes
  Cycle time: 0.1 to 999.9 seconds

• Output 2

User selectable as: Control with action opposite that of Output 1 (heating or cooling)
- Process or deviation alarm with flashing alarm message
- Process or deviation alarm without alarm message
- Alarm with separate high and low set points
- Hysteresis: 1 to 9999° or units switching differential

Line Voltage/Power
- 100-240V~ (ac), -15%, +10%[4]; (85-264V~ [ac]) 50/60Hz, ±5%
- 12-24V≂ (ac/dc), +10%, -15%; (10-26V≂ [ac/dc]) 50/60Hz, ±5%
- Fused internally(factory replaceable only) Slo-Blo® type (time-lag):
  1A, 250V for high voltage versions
  2A, 250V for low voltage versions
- Maximum power consumption: 12VA (100 to 240V~), 7VA (12 to 24V≂)
- Data retention upon power failure via non-volatile memory

Operating Environment[3]
- 0 to 65°C (32 to 149°F).
- 0 to 90% RH, non-condensing

Storage Temperature
- -40° to 85°C (-40° to 185°F)

Terminals
- #6 compression universal head screw terminals, accepts 20-14 gauge wire. Torque to 1.4 Nm (12 in-lb).

Controller Weight
- 0.2 kg (0.4 lb)

Shipping Weight
- 0.34 kg (0.75 lb)

Dimensions
- Compact 1/16 DIN size and IP65[4] (NEMA 4X), front panel make the Series 93 easy to apply and maintain in a wide variety of applications. The unique mounting bezel, gasket and collar make installation a snap.

Overall Height:	55 mm	(2.1 inches)
Width:	55 mm	(2.1 inches)
Depth:	120 mm	(4.7 inches)
Bezel Height:	55 mm	(2.1 inches)
Width:	55 mm	(2.1 inches)
Depth:	15 mm	(0.6 inches)
Chassis Height:	45 mm	(1.8 inches)
Width:	45 mm	(1.8 inches)
Depth:	105 mm	(4.1 inches)

Agency Approvals
- UL508 listed, c-UL, CE, IP65 (NEMA 4X), File #E102269
- CE:
  89/336/EEC (EN 61326)
  73/23/EEC (EN61010-1)

1 Electromechanical relays warranted for 100,000 closures only. Solid-state switching devices recommended for applications requiring fast cycle times or extended service life.
2 Switching inductive loads (relay coils, etc.) requires using an RC suppressor.
3 Operating environment is 0 to 60°C for line voltage exceeding 240V.
4 To effect IP65 (NEMA 4X) rating requires a minimum mounting panel thickness of 1.5 mm (0.06 inch) and surface finish not rougher than 812μ mm (0.32μ inch). Use Greenlee punch 60287.

Series 93 Model Number Information

Ordering Information

(2219)

93 _ _ - 1 _ _ _ - 0 0 _ _

Part Number
Microprocessor-based
1/16 DIN, Single Input, Dual Output,
Two-, Four-Digit Displays

IP65/NEMA 4X[1] Option
A = Without IP65/NEMA 4X Rating
B = With IP65/NEMA 4X Rating

CE Option
A = Without CE
B = With CE

Output 1
C = Switched dc output, non-isolated
D = Electromechanical relay, Form C, 5A, without contact suppression[2,3]
F = Process, 4-20mA (dc), non-isolated
K = Solid-state relay, Form A, 0.5A, without contact suppression[3]

Output 2
A = None
C = Switched dc output, non-isolated
D = Electromechanical relay, Form C, 5A, without contact suppression[2,3]
K = Solid-state relay, Form A, 0.5A, without contact suppression[3]

Line Voltage/Power
0 = 100 to 240V~ (ac) nominal (high voltage)
1 = 12 to 24V≂ (ac/dc) (low voltage)
X = Custom Parameters

Display
Upper/Lower
RR = Red/Red
RG = Red/Green
GR = Green/Red
GG = Green/Green
XX = Custom Overlay

[1] To effect IP65/NEMA 4X rating requires a minimum mounting panel thickness of 1.5 mm (0.06 inch) and surface finish not rougher than 812µ mm (0.32µ inch). Use Greenlee punch #60287.

[2] Electromechanical relays warranted for 100,000 closures only. Solid-state switching devices recommended for applications requiring fast cycle times or extended service life.

[3] Switching inductive loads (relay coils, etc.) requires using an RC suppressor. Quencharc from ITW PAKTRON is recommended, Watlow part number 0804-0147-0000.

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Appendix

Declaration of Conformity
Series 93

WATLOW Winona, Inc.
1241 Bundy Boulevard
Winona, Minnesota 55987 USA

CE

Declares that the following product: ***English***

Designation:	Series 93
Model Number(s):	93 (A or B) B – 1 (C, D, F or K) (A , C, D, or K) (0 or 1) – (Any four letters or numbers)
Classification:	Temperature control, Installation Category II, Pollution degree 2
Rated Voltage:	100 to 240 V~ (ac) or 12 to 24 V≂ (ac or dc)
Rated Frequency:	50 or 60 Hz
Rated Power Consumption:	12VA maximum (100 to 240 V~ units), 7 VA (12 to 24 V≂ units)

Meets the essential requirements of the following European Union Directives by using the relevant standards show below to indicate compliance.

89/336/EEC Electromagnetic Compatibility Directive

EN 61326:1997 With A1:1998 – Electrical equipment for measurement, control and laboratory use – EMC requirements (Industrial Immunity, Class A Emissions).
EN 61000-4-2:1996 With A1, 1998 – Electrostatic Discharge Immunity
EN 61000-4-3:1997 – Radiated Field Immunity
EN 61000-4-4:1995 – Electrical Fast-Transient / Burst Immunity
EN 61000-4-5:1995 With A1, 1996 – Surge Immunity
EN 61000-4-6:1996 – Conducted Immunity
EN 61000-4-11:1994 Voltage Dips, Short Interruptions and Voltage Variations Immunity
EN 61000-3-2:1995 With A1-3:1999 – Harmonic Current Emissions
EN 61000-3-3:1995 With A1:1998 – Voltage Fluctuations and Flicker

73/23/EEC Low-Voltage Directive

EN 61010-1:1993 With A1:1995 Safety Requirements of electrical equipment for measurement, control and laboratory use. Part 1: General requirements

déclare que le produit suivant : ***Français***

Désignation :	Series 93
Numéros de modèles :	93 (A or B) B – 1 (C, D, F ou K) (A , C, D, ou K) (0 ou 1) (N'importe quelle combinaison de quatre lettres ou chiffres)
Classification :	Régulation de température, Catégorie d'installation II, Degré de pollution 2
Tension nominale :	100 à 240 V~ (c.a) ou 12 à 24 V ≂ (c.a ou c.c)
Fréquence nominale :	50 ou 60 Hz
Consommation d'alimentation nominale :	12 VA maximum (100 à 240 V~ unités), 7 VA (12 à 24 V ≂ unités)

Répond aux normes essentielles des directives suivantes de l'Union européenne en utilisant les standards normalisés ci-dessous qui expliquent les normes auxquelles répondre :

Directive 89/336/CEE sur la compatibilité électromagnétique

EN 61326:1997 avec A1 :1998 – Matériel électrique destiné à l'étalonnage, au contrôle et à l'utilisation en laboratoire – Exigences CEM (Immunité industrielle, Émissions de catégorie A).
EN 61000-4-2:1996 Avec A1, 1998 – Immunité aux décharges électrostatiques
EN 61000-4-3:1997 – Immunité aux champs de radiation
EN 61000-4-4:1995 – Immunité contre les surtensions électriques rapides/ Rafale
EN 61000-4-5:1995 avec A1, 1996 – Immunité contre les surtensions
EN 61000-4-6:1996 – Immunité conduite
EN 61000-4-11:1994 Immunité contre les écarts de tension, interruptions courtes et variations de tension
EN 61000-3-2:1995 avec A1-3 :1999 – Emissions de courant harmoniques
EN 61000-3-3:1995 avec A1 :1998 – Fluctuations et vacillements de tension

Directive 73/23/CEE sur les basses tensions

EN 61010-1:1993 avec A1 :1995 Normes de sécurité du matériel électrique pour la mesure, le contrôle et l'utilisation en laboratoire. 1ère partie : Conditions générales

(2186)

Erklärt, dass das folgende Produkt: ***Deutsch***

Bezeichnung:	Series 93
Modell-Nummern:	93 (A oder B) B – 1 (C, D, F oder K) (A , C, D, oder K) (0 oder 1) - (Beliebige vier Ziffern oder Buchstaben)
Klassifikation:	Temperaturregler, Installationskategorie II, Verschmutzungsgrad 2
Nennspannung:	100 bis 240 V~ (ac) oder 12 bis 24 V ≂ (AC oder DC)
Nennfrequenz:	50 oder 60 Hz
Nennstromverbrauch:	12 VA max. (100 bis 240 V~ -Systeme), 7 VA (12 bis 24 V ≂ -Systeme)

Erfüllt die wichtigsten Normen der folgenden Anweisung(en) der Europäischen Union unter Verwendung des wichtigsten Abschnitts bzw. der wichtigsten Abschnitte die unten zur Befolgung aufgezeigt werden.

89/336/EEC Elektromagnetische Kompatibilitätsrichtlinie

EN 61326:1997 mit A1:1998 – Elektrisches Gerät für Messung, Kontrolle und Laborgebrauch – EMV-Anforderungen (Störfestigkeit Industriebereich, Klasse A Emissionen)
EN 61000-4-2:1996 mit A1, 1998 – Störfestigkeit gegen elektronische Entladung
EN 61000-4-3:1997 – Störfestigkeit gegen Strahlungsfelder
EN 61000-4-4:1995 – Störfestigkeit gegen schnelle Stöße/Burst
EN 61000-4-5:1995 mit A1, 1996 – Störfestigkeit gegen Überspannung
EN 61000-4-6:1996 – Geleitete Störfestigkeit
EN 61000-4-11:1994 Störfestigkeit gegen Spannungsabfall, kurze Unterbrechungen und Spannungsschwankungen
EN 61000-3-2:1995 mit A1-3:1999 – Harmonische Stromemissionen
EN 61000-3-3:1995 mit A1:1998 – Spannungsfluktationen und Flimmern
EN 61000-3-3: 1995 Grenzen der Spannungsschwankungen und Flimmern

73/23/EEC Niederspannungsrichtlinie

EN 61010-1:1993 mit A1:1995 Sicherheitsanforderungen für elektrische Geräte für Messungen, Kontrolle und Laborgebrauch. Teil 1: Allgemeine Anforderungen

Declara que el producto siguiente: ***Español***

Designación:	Series 93
Números de modelo:	93 (A o B) B – 1 (C, D, F o K) (A , C, D, o K) (0 o 1) - (Cualesquiera cuatro letras o números)
Clasificación:	Control de temperatura, Categoría de instalación II, Grado de contaminación 2
Tensión nominal:	100 a 240 V~ (CA) o 12 a 24 V ≂(CA o CD)
Frecuencia nominal:	50 o 60 Hz
Consumo nominal de energía:	12 VA máximo (unidades de 100 a 240 V~), 7 VA (unidades de 12 a 24 V ≂)

Cumple con los requisitos esenciales de las siguientes Directrices de la Unión Europea mediante el uso de las normas aplicables que se muestran a continuación para indicar su conformidad.

89/336/EEC Directriz de compatibilidad electromagnética

EN 61326:1997 CON A1:1998.– Equipo eléctrico para medición, control y uso en laboratorio – Requisitos EMC (Inmunidad industrial, Emisiones Clase A).
EN 61000-4-2:1996 con A1, 1988 – Inmunidad a descarga electrostática
EN 61000-4-3:1997 – Inmunidad a campo radiado
EN 61000-4-4:1995 – Inmunidad a incremento repentino/rápidas fluctuaciones eléctricas transitorias
EN 61000-4-5:1995 con A1, 1996 – Inmunidad a picos de voltaje o corriente
EN 61000-4-6:1996 – Inmunidad por conducción
EN 61000-4-11:1994 Inmunidad a caídas de voltaje, variaciones y pequeñas interrupciones de voltaje
EN 61000-3-2:1995 con A1-3:1999 – Emisiones de corriente armónica
EN 61000-3-3:1995 con A1:1998 – Fluctuaciones de voltaje y centelleo.

73/23/EEC Directriz de bajo voltaje

EN 61010-1:1993 con A1:1995 Requisitos de seguridad de equipo eléctric para medición, control y uso en laboratorio. Parte 1: Requisitos generales

Jim Boigenzahn Name of Authorized Representative	Winona, Minnesota, USA Place of Issue
General Manager Title of Authorized Representative	August 2001 Date of Issue

Signature of Authorized Representative

Notes

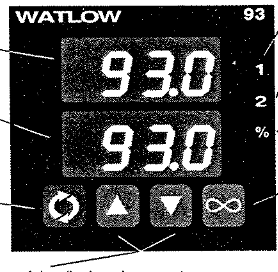
Series 93 Quick Reference

Keys and Displays

Upper Display: Indicates the process value, actual temperature, operating parameter values or an open sensor. When powering up, the Process display will be blank for five seconds.
• To set to blank: set [dSP] to [SEt] in the Setup Menu.

Lower Display: Indicates the set point, output value, parameters for data in the upper display, or error and alarm codes.
• To set to blank: set [dSP] to [Pro] in the Setup Menu.

Advance Key: Press to step through the Operations, Setup and Calibration Menus. In the Auto mode, new data is self-entering in five seconds.



Output 1 Indicator Light: Lit when Output 1 is energized.

Output 2 Indicator Light: Lit when Output 2 is active. This output can be configured as a control or alarm output.

% Percent Power Indicator Light
• Lit: the controller is in Manual operation. Press the ∞Infinity key twice to enter Automatic operation.
• Blinking: press the ∞Infinity key to toggle between Auto and Manual. Returns to its previous state and stops blinking if the ∞Infinity key is not pressed within five seconds.

Infinity Key
• Press once to clear any latched alarms. Also disables alarm output if silencing is enabled.
• Press again within five seconds to change from Auto to Manual or vice versa. While in Manual mode, percent power is in the lower display.

Up-arrow and Down-arrow Keys: Increases or decreases the value of the displayed parameter.
• Press lightly to increase or decrease the value by one.
• Press and hold down to increase or decrease the displayed value at a rapid rate. New data will self-enter in five seconds, or can be entered by pressing the Advance Key.
• Press both keys simultaneously for three seconds to enter the Setup Menu. The [LOC] parameter appears.
• Continue pressing both keys to enter the Calibration Menu.

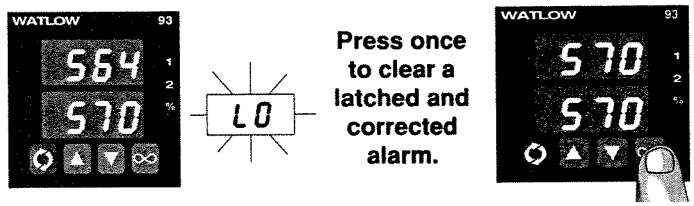
Alarms

A process alarm sets an absolute temperature. When the process exceeds that absolute temperature limit, an alarm occurs. The process alarm set points may be independently set high and low. Under the Setup Menu, select the type of alarm output with the [Ot2] parameter. [PrA] sets a process alarm with alarm message displayed. [Pr] sets a process alarm with no alarm message displayed.

A deviation alarm alerts the operator when the process strays too far from the set point. The operator can enter independent high and low alarm settings. The reference for the deviation alarm is the set point. Any change in set point causes a corresponding shift in the deviation alarm. [dEA] sets a deviation alarm with alarm message displayed. [dE] sets a deviation alarm with no alarm message displayed.

Example: If your set point is 100°F, and a deviation alarm is set to +7°F as the high limit, and -5°F as the low limit, the high alarm trips at 107°F, and the low alarm at 95°F. If you change the set point to 130°F, the alarms follow the set point and trip at 137°F and 125°F.

To clear an alarm:
- First correct the alarm condition, then...
- **If the alarm is latching:**
  Clear it manually; press the ∞Infinity key once as soon as the process temperature is inside the [HSA] parameter alarm limit.
- **If the alarm is non-latching:**
  The alarm clears itself automatically as soon as the process temperature is inside the [HSA] parameter.

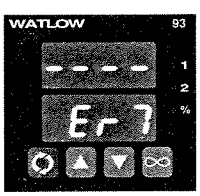


Flashing [LO] or [HI] in the lower display indicates an alarm when [Ot2] is set to [PrA] or [dEA]. The lower display alternately shows information from the current parameter and the [LO] or [HI] alarm message at one-second intervals. The alarm output is de-energized and the Output 2 indicator light is lit.

Alarm Silencing is available with the deviation alarm and has two uses:
When [SIL] is set to "on," the operator must manually disable the alarm by pressing the ∞Infinity key once on initial power up (in either the latching or non-latching mode). Alarm silencing disables the alarm output relay. However, the Output 2 indicator light (also the lower display when [Ot2] is set to [dEA]) shows an alarm condition until the process value is within the "safe" region of the deviation alarm band. Once the process value crosses into the "safe" region, both a latching or a non-latching alarm is ready. Any future deviation outside this safe band triggers an alarm.

Latching: Both process and deviation alarms can be latching or non-latching. When the alarm condition is removed a **non-latching alarm automatically** clears the alarm output. You must **manually clear a latching alarm** before it will disappear.

Errors



Four dashes [----] in the upper display indicate a Series 93 error. The error code is visible in the lower display.

[Er2] **- Sensor underrange error (applies only to RTD units)**
The sensor input generated a value lower than the allowable signal range, or the analog-to-digital circuitry malfunctioned. Enter a valid input. Make sure the [In] parameter (Setup Menu) and the DIP switch settings both match your sensor.

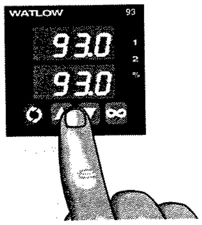
[Er4] **- Configuration error**
The controller's microprocessor is faulty; call the factory.

[Er5] **- Nonvolatile checksum error**
The nonvolatile memory checksum discovered a checksum error. Unless a momentary power interruption occurred while the controller was storing data, the nonvolatile memory is faulty. Call the factory.

[Er6] **- Analog-to-digital underflow error**
The analog-to-digital circuit is underrange. An open or reversed polarity sensor is the most likely cause. Check the sensor; if the connection is good and functions properly, call the factory. The analog-to-digital underrange voltage is too low to convert an analog-to-digital signal. Make sure the In parameter matches your sensor and the DIP switches are set accordingly.

[Er7] **- Analog-to-digital overflow error**
The analog-to-digital circuit is overrange. An open or reversed polarity sensor is the most likely cause. Check the sensor; if the connection is good, and the sensor functions properly, call the factory. The analog-to-digital overrange voltage is too high to convert an analog-to-digital signal. Make sure the [In] parameter (Setup Menu) matches your sensor and the DIP switches are set accordingly.

Setup Menu



Enter the Setup Menu by pressing the ⊙Up-arrow and ⊙Down-arrow keys simultaneously for three seconds. The lower display shows the [LOC] Lock parameter, and the upper display shows its current level. All keys are inactive until you release both keys. You can reach the Lock parameter from anywhere. Use the ⊛Advance key to move through the menus and the ⊙Up-arrow and ⊙Down-arrow keys to select data. You will not see all parameters in this menu, depending on the controller's configuration and model number.

Setup Menu
- [LOC] Lock
- [In] Input
- [dEC] Decimal*
- [C_F] Celsius - Fahrenheit*
- [rL] Range Low
- [rH] Range High
- [Ot1] Output 1
- [HSC] Hysteresis Control
- [Ot2] Output 2
- [HSA] Hysteresis Alarm*
- [LAt] Latching*
- [SIL] Silencing*
- [rtd] RTD*
- [rP] Ramping
- [rt] Rate*
- [PL] Power Limiting*
- [dSP] Display

* Parameter may not always appear.

Note:
Do not enter any values here; make photocopies instead.

Parameter	Value	Range	Factory Default	Appears If:
[LOC]		0 - 4	0	
[In]		[J], [H], [t], [n], [S1], [rtd], [rt.d], [0-5], [420]	[J]	DIP switch-selectable.
[dEC]		0, 0.0, 0.00	0	[In] is set to [0-5] or [420]
[C_F]		[C] or [F]	Dependent on [dFL]	[In] is set to [J], [H], [t], [n], [S1], [rtd], or [rt.d]
[rL]		[rL] to [rH]	Input dependent.	
[rH]		[rH] to [rL]	Input dependent.	
[Ot1]		[ht] or [CL]	[ht]	
[HSC]		1 to 55, 0.1 to 5.5, 0.01 to 0.55°C 1 to 99, 0.1 to 9.9, 0.01 to 0.99°F	2, 0.2, 0.02°C 3, 0.3, 0.03°F	
[Ot2]		[Con] Control [PrA] Process Alarm [Pr] Process with no alarm message [dEA] Deviation alarm [dE] Deviation with no alarm message [no] None	[Con]	
[HSA]		1 to 5555, 0.1 to 555.5, 0.01 to 55.55°C 1 to 9999, 0.1 to 999.9, 0.01 to 99.99°F	2, 0.2, 0.02°C 3, 0.3, 0.03°F	[Ot2] is not set to [Con] or [no]
[LAt]		[LAt] or [nLA]	[nLA]	[Ot2] is not set to [Con] or [no]
[SIL]		[On] or [OFF]	[OFF]	[Ot2] is set to [dEA] or [dE]
[rtd]		[JIS] or [din]	[din]	[In] is set to [rtd] or [rt.d]
[rP]		[Str] is set to Ramping on power up [on] is set to Ramping to set point always [OFF] is set to None	[OFF]	
[rt]		0 to 9999	100°/hr	[rP] is not set to [OFF]
[PL]		0 to 100	100	
[dSP]		[nor] normal [SEt] Set Point (lower only) [Pro] Process (upper only)	[nor]	

Operation Menu

Operation Menu
- [93] Control Set Point
- [Pb1] Proportional Band 1
- [rE1] Reset 1*
- [It1] Integral 1*
- [rA1] Rate 1*
- [dE1] Derivative 1*
- [Ct1] Cycle Time 1*
- [ALO] Alarm Low*
- [AH1] Alarm High*
- [Pb2] Proportional Band 2*
- [rE2] Reset 2*
- [It2] Integral 2*
- [rA2] Rate 2*
- [dE2] Derivative 2*
- [Ct2] Cycle Time 2*
- [CAL] Calibration Offset
- [AUt] Autotune

* Parameter may not always appear.

Parameter	Value	Range	Factory Default
[Pb1]		If [dFL] is set to [US]: 0 to 555°C/0 to 999°F/0 to 999 Units 0 to 55.5°C/0 to 99.9°F/0 to 99.9 Units 0 is set to on-off control. [HSC] is set to switch differential If [dFL] is set to [SI]: 0.0 to 999.9% of span	25°F 2.5°F 3%
[rE1]		0.00 to 9.99 repeats/minute 0.00 = No Reset. Won't appear if [Pb1] is set to 0 or [dFL] is set to [SI].	0.00 repeats/minute
[It1]		0.0 to 99.9 minutes/rpt. 0.00 = No Integral. Won't appear if [Pb1] is set to 0 or [dFL] is set to [US].	00.0 minutes/repeat
[rA1]		0.00 to 9.99 minutes 0.00 = No Rate. Will not appear if [Pb1] is set to 0 or [dFL] is set to [SI].	0.00 minutes
[dE1]		0.00 to 9.99 minutes. 0.00 = No Derivative. Won't appear if [Pb1] is set to 0 or [dFL] is set to [US].	0.00 minutes
[Ct1]		0.1 to 999.9 Won't appear if [Pb1] = 0, or [420].	5.0 seconds
[Pb2]		Same as [Pb1], [Pb2] lower limit = 1, 0.1, 0.01	
[rE2]		Same range as [rE1].	
[It2]		Same range as [It1].	
[rA2]		Same range as [rA1].	
[dE2]		Same range as [dE1].	
[Ct2]		Same range as [Ct1].	
[ALO] Deviation [dE] Process [Pr]		-999 to 0 [rL] to [AH1] Will not appear if [Ot2] is set to [no] or [Con].	-999 [rL]
[AH1] Deviation [dE] Process [Pr]		0 to 999 [ALO] to [rH] Will not appear if [Ot2] is set to [no] or [Con].	999 [rH]
[CAL]		±100°C/±180°F/±180 Units	0
[AUt]		0 to 3	0

Appendix

Notes

Notes

Notes

Notes

Watlow Winona

Watlow Winona is a division of Watlow Electric Mfg. Co., St. Louis, Missouri, a manufacturer of industrial electric heating products, since 1922. Watlow begins with a full set of specifications and completes an industrial product that is manufactured totally in-house, in the U.S.A. Watlow products include electric heaters, sensors, controls and switching devices. The Winona operation has been designing solid-state electronic control devices since 1962, and has earned the reputation as an excellent supplier to original equipment manufacturers. These OEMs depend upon Watlow Winona to provide compatibly engineered controls that they can incorporate into their products with confidence. Watlow Winona resides in a 100,000-square-foot marketing, engineering and manufacturing facility in Winona, Minnesota.

How to Reach Us

TOTAL
CUSTOMER
SATISFACTION
3 Year Warranty

Quality and Mission Statement:

Watlow Winona will be the world's best supplier of industrial temperature control products, services, and systems by exceeding our customers', employees', and shareholders' expectations.

Contact

Your Authorized Watlow Distributor is:

- or Phone: 507/454-5300.
- Fax: 507/452-4507.
- For technical support, ask for an Applications Engineer.
- To place an order, ask for Customer Service.
- To discuss a custom option, ask for a Series 93 Product Manager.

Warranty

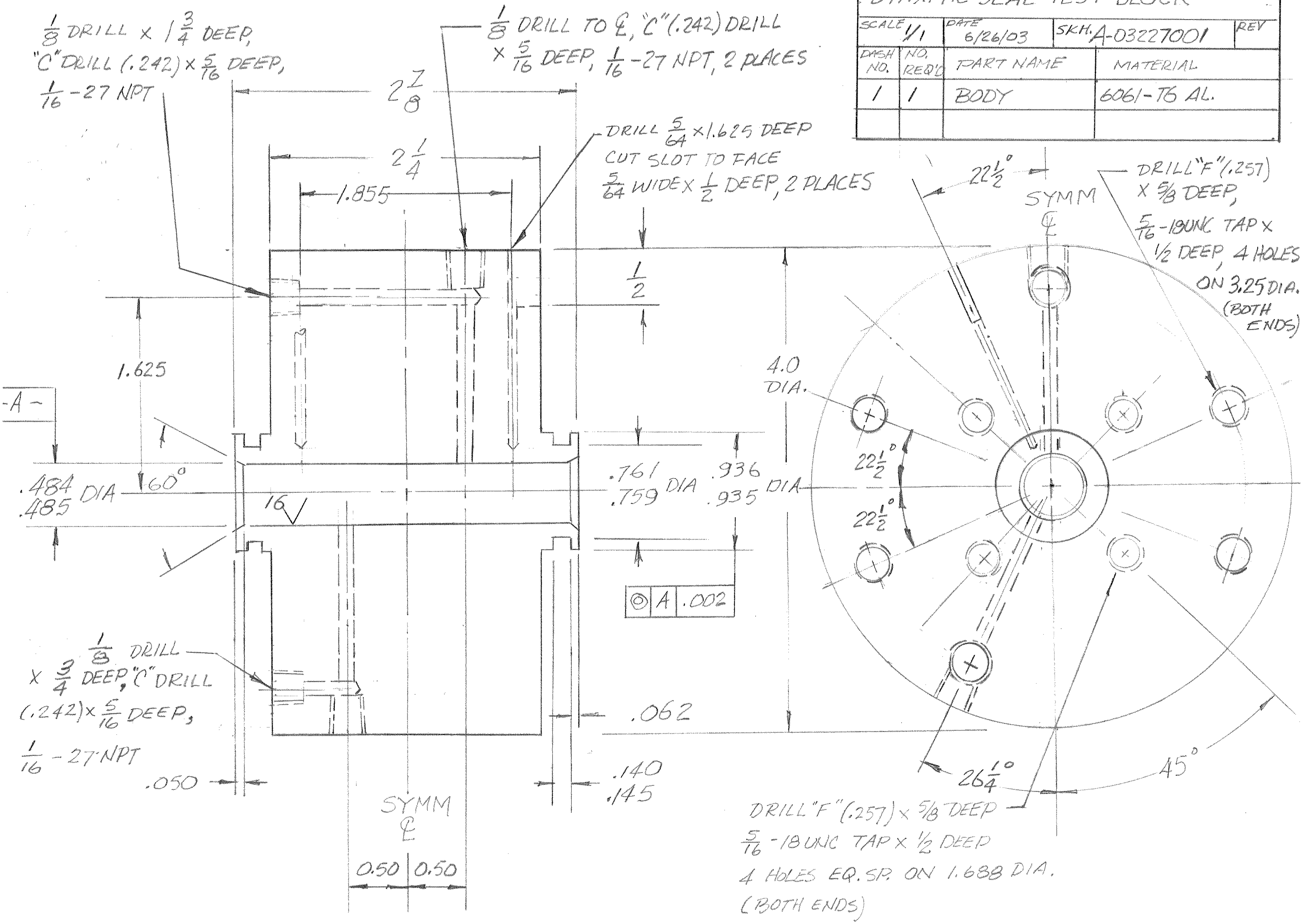
The Watlow Series 93 is warranted to be free of defects in material and workmanship for 36 months after delivery to the first purchaser for use, providing that the units have not been misapplied. Since Watlow has no control over their use, and sometimes misuse, we cannot guarantee against failure. Watlow's obligations hereunder, at Watlow's option, are limited to replacement, repair or refund of purchase price, and parts which upon examination prove to be defective within the warranty period specified. This warranty does not apply to damage resulting from transportation, alteration, misuse, or abuse.

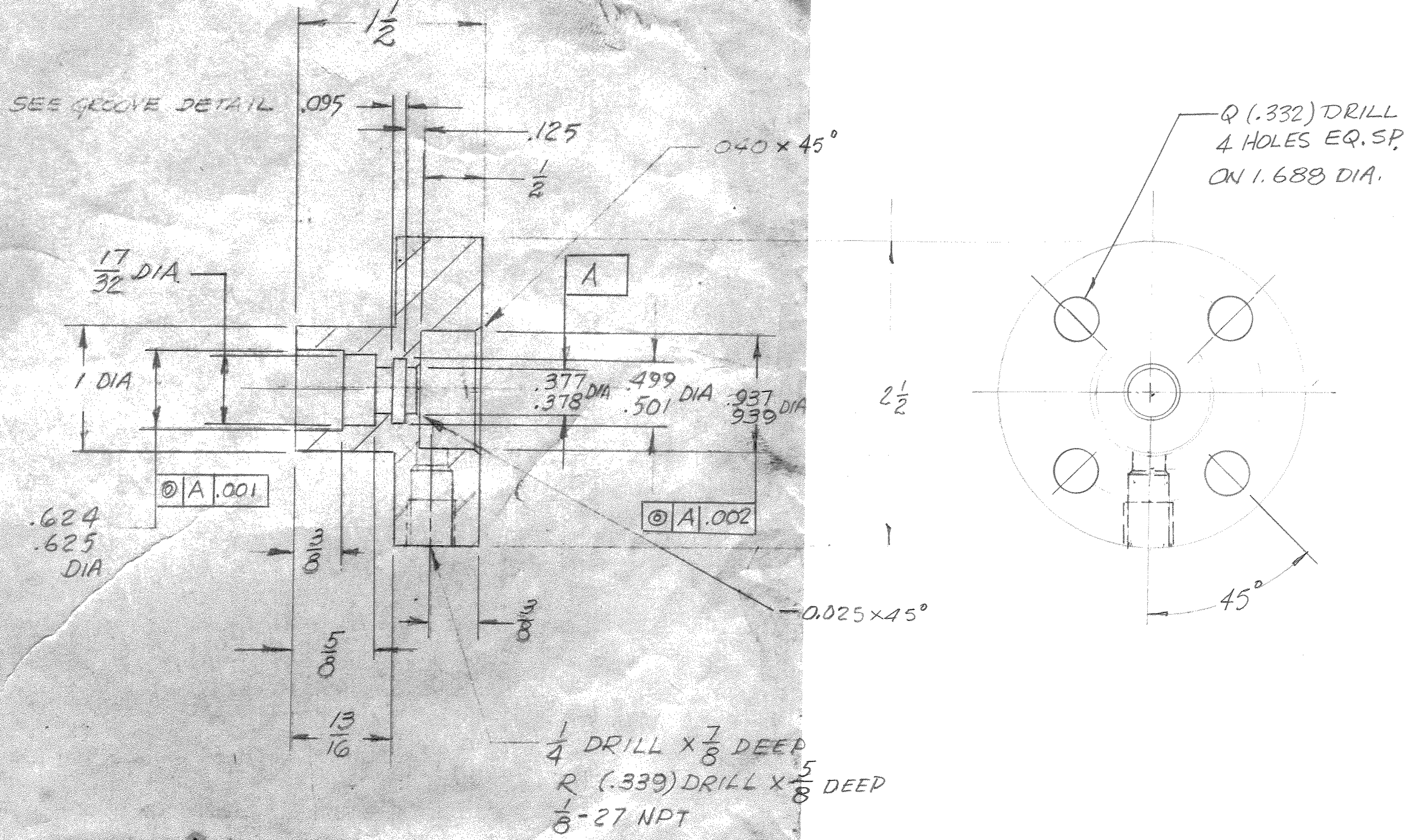
Returns

- Call or fax Customer Service for a Return Material Authorization (RMA) number before returning a controller.
- Put the RMA number on the shipping label, and also on a description of the problem.
- 20% of net price restocking charge applies to all standard units returned to stock.

APPENDIX B
PART AND ASSEMBLY DRAWINGS

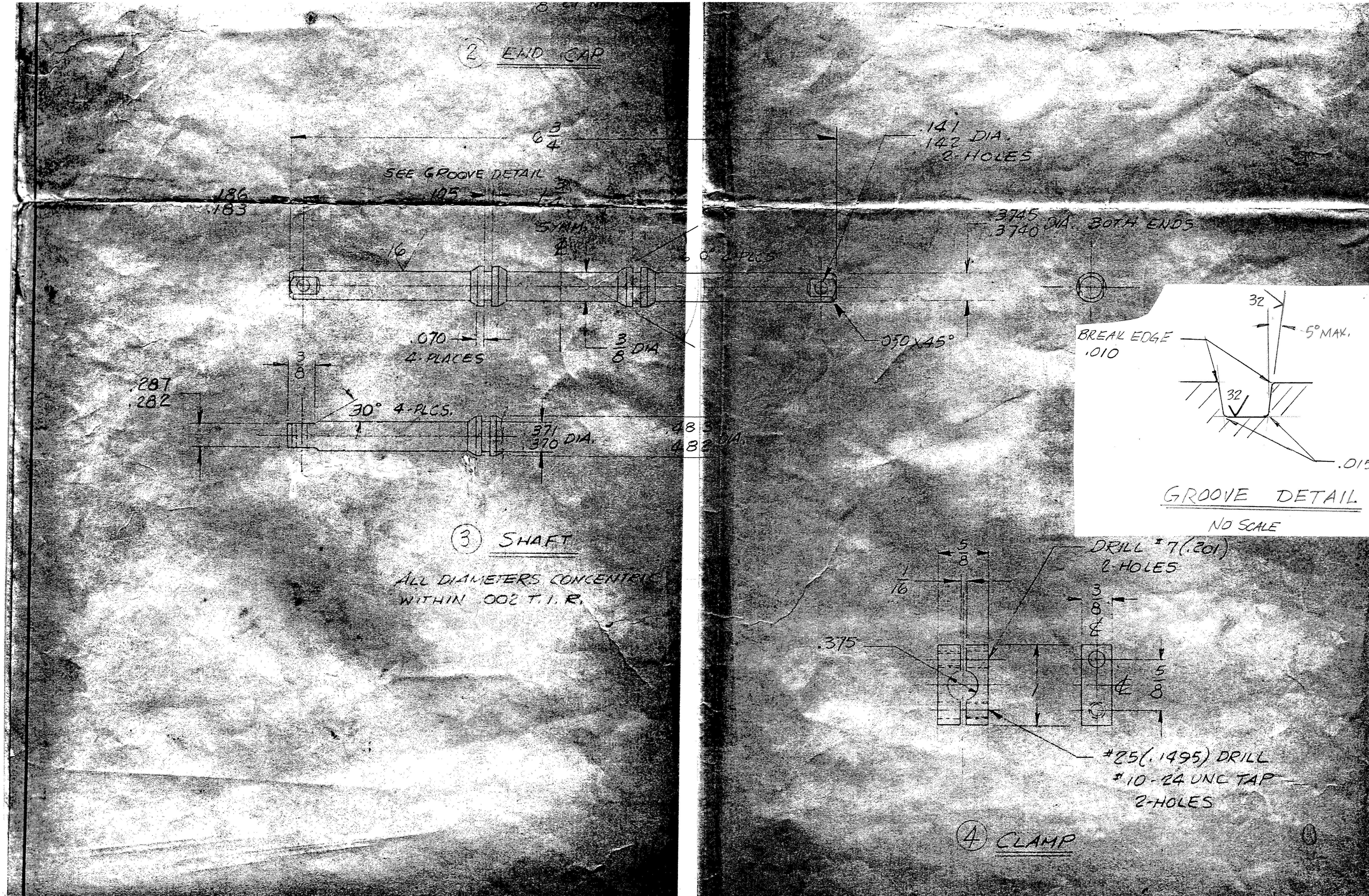
SOUTHWEST RESEARCH INSTITUTE				
DYNAMIC SEAL TEST BLOCK				
SCALE 1/1	DATE 6/26/03	SKH. A-03227001		REV
DASH NO.	NO. REQ'D	PART NAME	MATERIAL	
1	1	BODY	6061-T6 AL.	





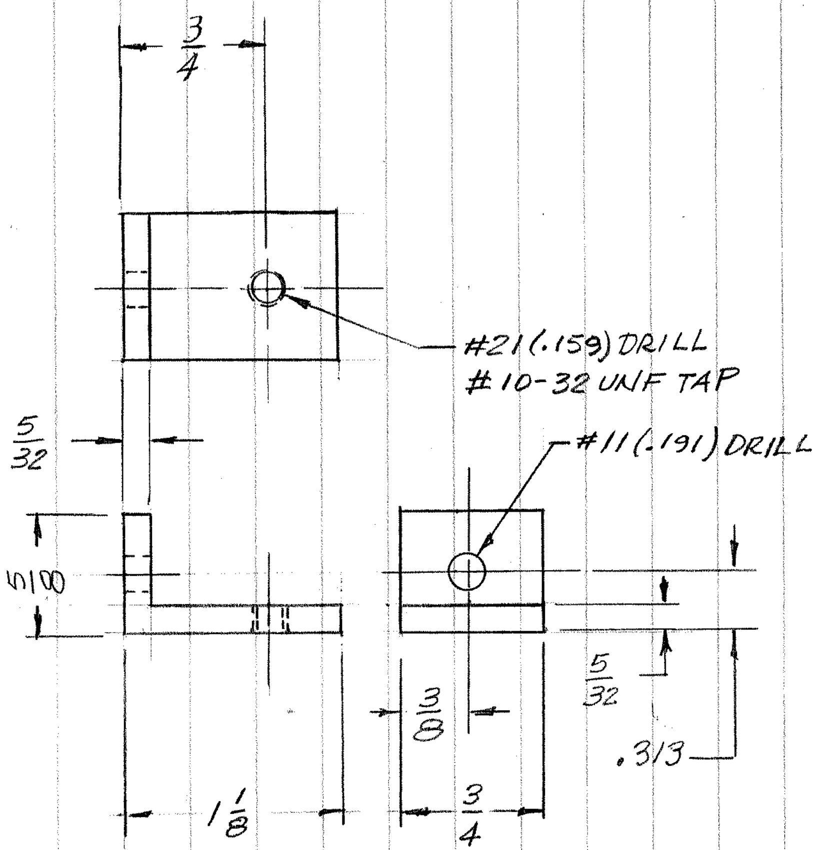
② END CAP

SK B 3227003



SKB-03227002

SOUTHWEST RESEARCH INSTITUTE				
DYNAMIC TEST RIG - PART DETAILS				
SCALE 1/1		DATE 08/04/03	SKH A-03227006	REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL	
1	1	ARM	6061-T6 AL.	



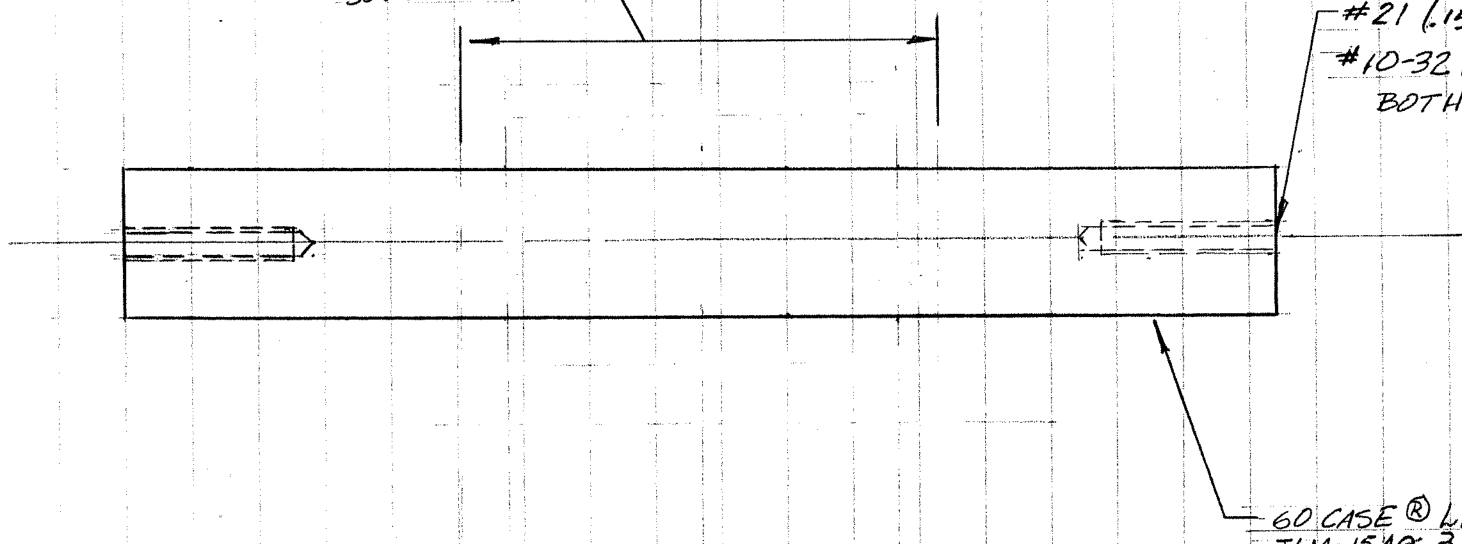
(1) ARM

SOUTHWEST RESEARCH INSTITUTE			
LINEARRACE® SHAFT			
SCALE 1/1	DATE 8/1/03	SKHA-03227008	REV
DASH NO.	NO REQ'D	PART NAME	MATERIAL
1	1	SHAFT	440C SS

NOTES: (1) SHAFT SUPPLIED BY OTHERS

(2) DO NOT APPLY CHUCK OR OTHER CLAMPING DEVICES TO MIDDLE $2\frac{1}{2}$ OF SHAFT - SURFACE MUST MAINTAIN SURFACE CONDITION AS SUPPLIED.

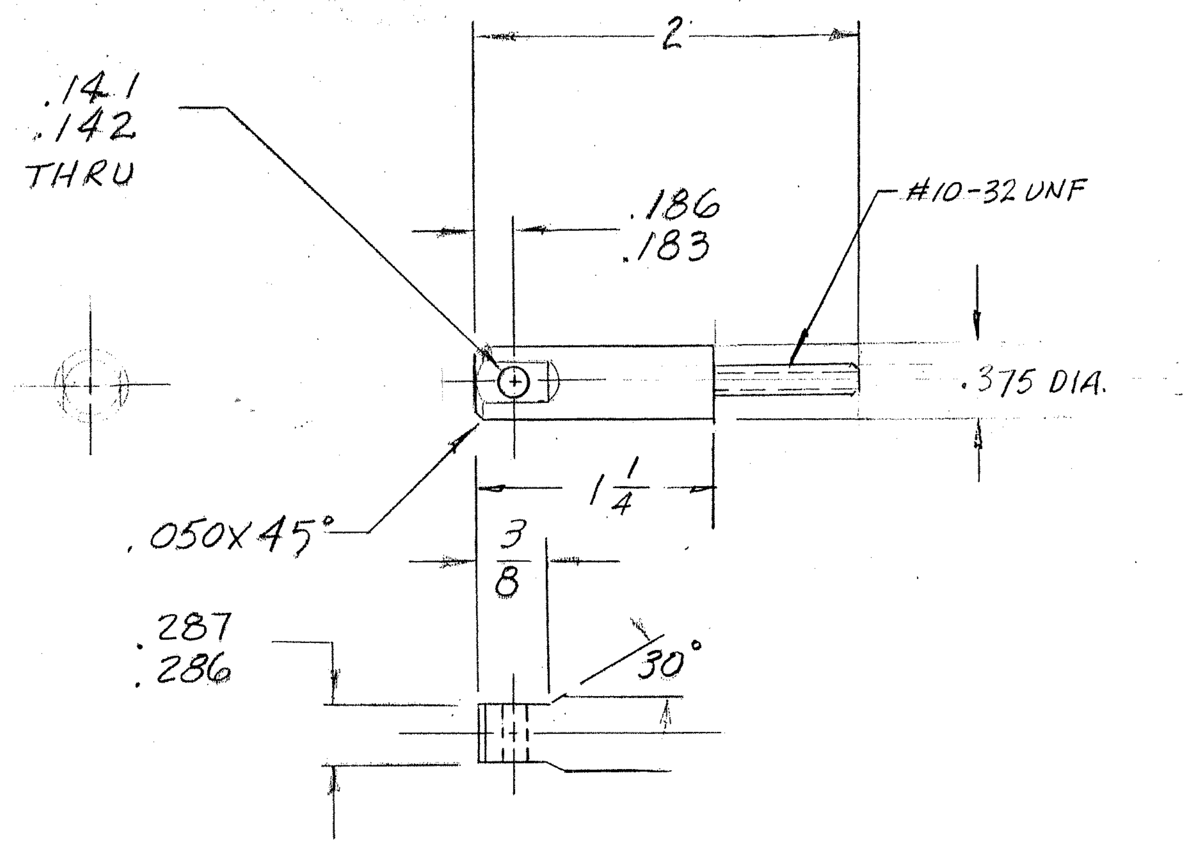
#21 (.159) DRILL x 1 DEE
#10-32 UNF TAP x $\frac{7}{8}$ DEEP
BOTH ENDS



60 CASE ® LINEARRACE ® SHAFT
TLM-~~1549~~ 1625 $\frac{3}{4}$ NOM. DIA x 6 LONG

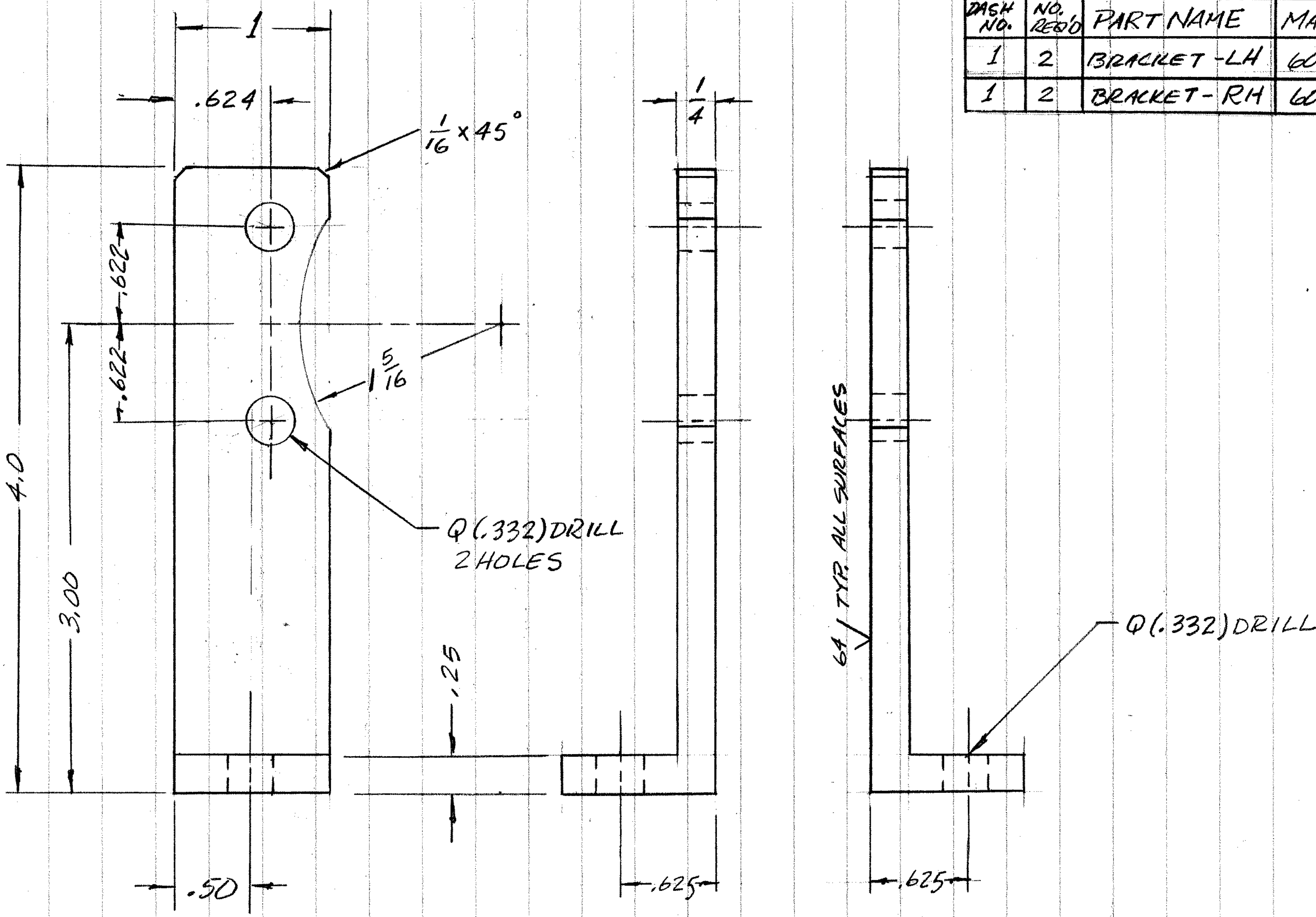
(1) LINEARRACE® SHAFT

SOUTHWEST RESEARCH INSTITUTE			
DYNAMIC TEST RIG - PART DETAILS			
SCALE 1/1	DATE 08/05/03	SKH A-03227009	REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL
1	1	STUD	18-8 SS



1 STUD

SOUTHWEST RESEARCH INSTITUTE			
DYNAMIC TEST RIG - PART DETAILS			
SCALE 1/1	DATE 08/07/03	SKH A-03227011	REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL
1	2	BRACKET - LH	6061-T6 AL
1	2	BRACKET - RH	6061-T6 AL

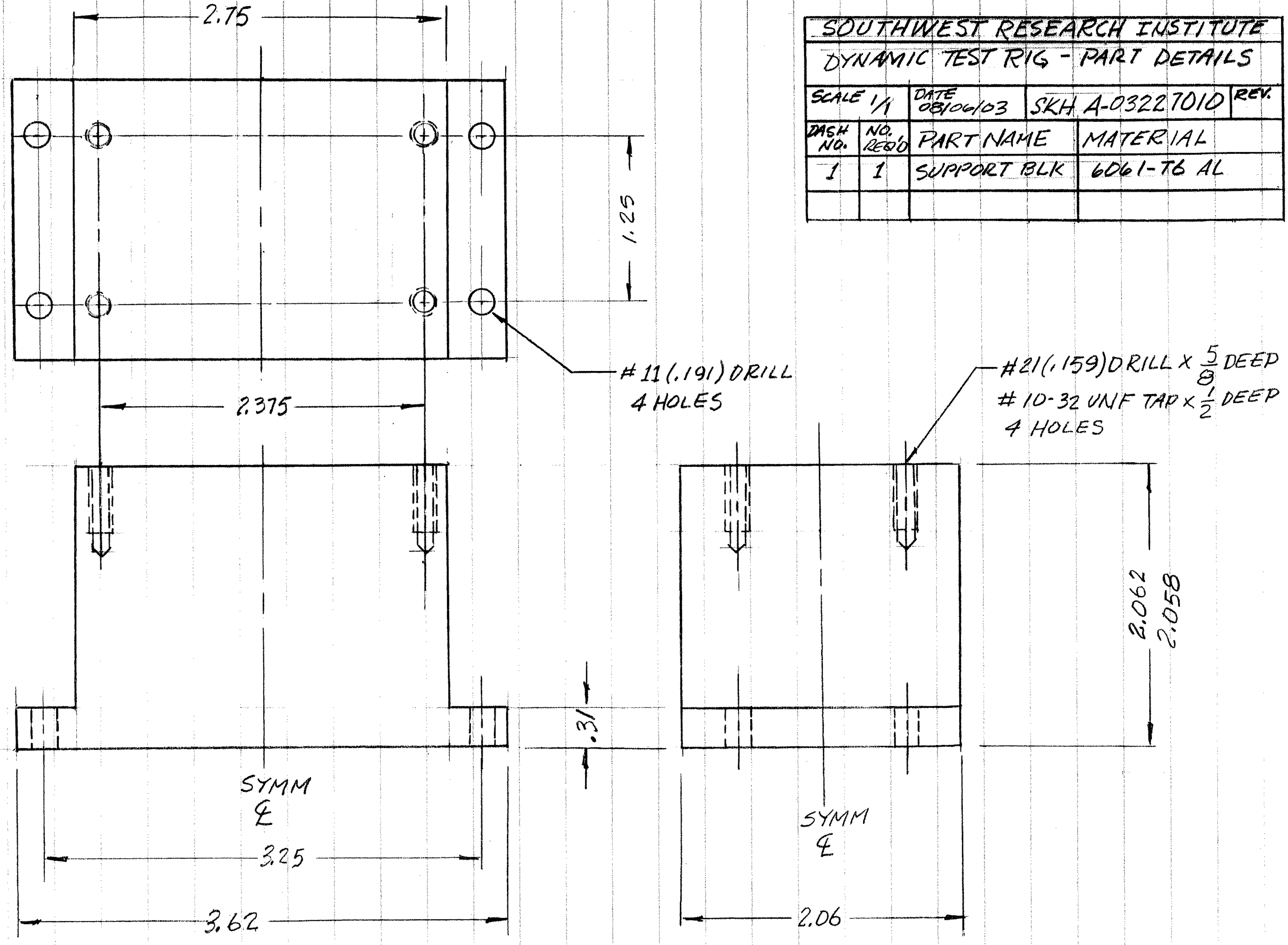


(1) BRACKET

LEFT HAND
2 REQ'D

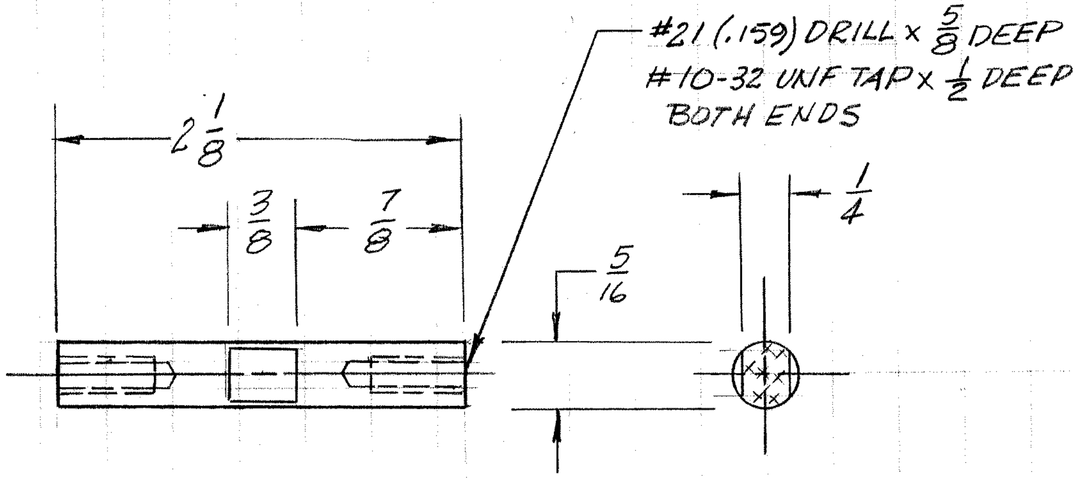
RIGHT HAND
2 REQ'D

SOUTHWEST RESEARCH INSTITUTE			
DYNAMIC TEST RIG - PART DETAILS			
SCALE 1/1	DATE 08/06/03	SKH A-03227010	REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL
1	1	SUPPORT BLK	6061-T6 AL



(1) SUPPORT BLOCK

SOUTHWEST RESEARCH INSTITUTE				
DYNAMIC TEST RIG - PART DETAILS				
SCALE 1/1	DATE 08/04/03	SKH A-03227007		REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL	
1	1	LINK ARM	6061-T6 AL.	

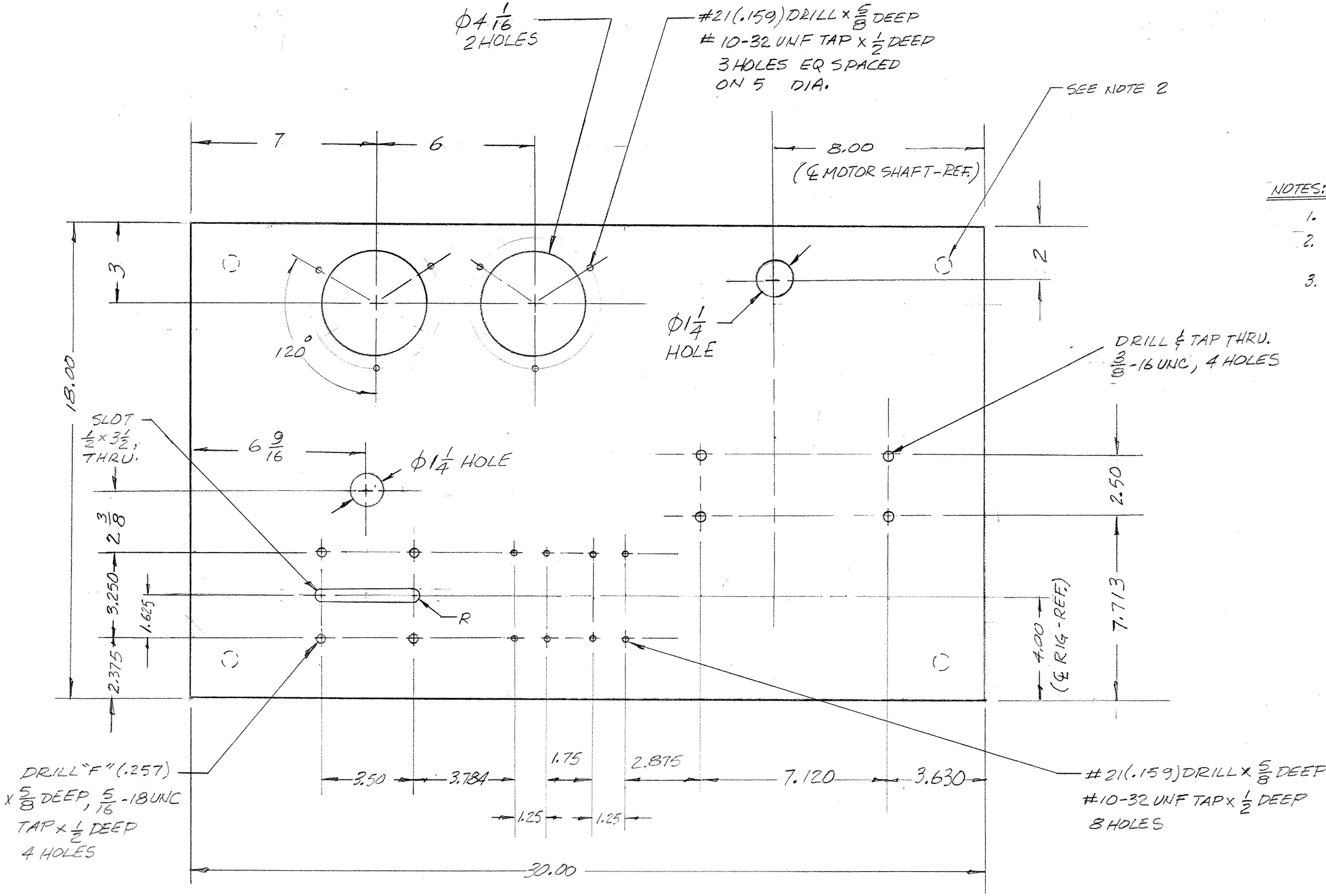


(1) LINK ARM

SOUTHWEST RESEARCH INSTITUTE				
DYNAMIC TEST RIG - SUPPORT PLATE				
SCALE 1/4	DATE 08/18/03	SKH B-03227012		REV.
DASH NO.	NO. REQ'D	PART NAME	MATERIAL	
1	1	SUPPORT PLATE	T200 AL	

NOTES:

1. BREAK SHARP EDGES 1/64
2. LOCATION OF HOLES FOR CORNER POST PER HAL KING
3. DECIMAL TOLERANCE ±.003
   FRACTION TOLERANCE ± 1/64



1 SUPPORT PLATE
1 REQ'D